JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

Vol. 34 NOVEMBER 1942 No. 11

Contents

All correspondence relating to the publication of papers **should be addressed to**

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Vol. 34 | November 1942 | No. 11

Ground Water—A Vital National Resource

By O. E. Meinzer, Charles B. Burdick and Samuel B. Morris

General Nature of the Current Problem—O. E. Meinzer

SINCE the dawn of the human race men have probably understood how to get water supplies from shallow wells. In the arid regions of the Old World ground water has been used extensively for irrigation since ancient times. Elsewhere, until in recent times, the withdrawal of water from wells has generally been on such a small scale and so widely scattered that the ground-water supplies have with good reason been considered inexhaustible.

In the last century some rather large ground-water developments were made, in both Europe and the United States, to provide pure water for public supplies. As methods of filtration and chlorination were perfected there was a notable trend toward the utilization of treated surface water for the large and rapidly growing cities, especially in this country, while wells were still used to supply most of the smaller municipalities and industries and to furnish most of the railroad water supplies. More recently, however, there has been an equally notable trend throughout this country to develop more and more ground-water supplies in ever larger quantities—

A symposium presented on June 24, 1942, at the Chicago Conference by O. E. Meinzer, Chief, Div. of Ground Water, Water Resources Branch, U.S. Geol. Survey, U.S. Dept. of Interior, Washington, D.C.; Charles B. Burdick, Hydr. & San. Engr., Alvord, Burdick & Howson, Engineers, Chicago; and Samuel B. Morris, Dean, School of Eng., Stanford Univ., Calif. Malcolm Pirnie, Cons. Engr., New York, also participated in this discussion. His contribution will be published at a later date.

generally not to replace surface-water supplies but to meet a great complex of new demands for water, out of all proportion to the increase in population (1).

Increased Use of Ground Water

The increased use of ground water was made practicable by radical improvements in the construction of water wells and in pumping machinery and by the development of methods of treatment of the ground water, to soften it and to remove iron and other objectionable mineral constituents. The "batteries" of small wells with fine screens that gave trouble more or less constantly have been replaced to a great extent by more reliable and more productive wells of larger diameter, some of them gravel-walled, and with durable screens that have large enough openings to permit development of large yields. With these wells came the deep-well turbine pumps, electrically driven and automatically controlled and often discharging directly into the mains at points advantageous to secure the proper pressure. These improvements in the wells and pumping machinery have reduced the cost of operating ground-water systems and have made these systems generally reliable and satisfactory (2).

In 1933 the U.S. Geological Survey estimated that, in the United States, about 6,500 public water supplies were derived from wells and about 3,500 derived from other sources (2). Another estimate, in 1939 (3), indicated that there were about 9,100 public water supply systems supplied from ground water (wells and springs) and about 3,300 supplied from streams and lakes. These two estimates are not directly comparable as to ground-water supplies, because the latter figures include the supplies obtained from springs; moreover, the estimate by the Geological Survey was purposely conservative and was probably too low. In the period from 1933 to 1939, however, a large number of new public water works were installed, largely promoted and financed by the Federal Government, and the great majority of them were supplied from wells. In 1933 it was estimated that nearly twenty million people in the United States depended on public water supplies derived from wells, which at 100 gpd. per capita would require about two billion gallons a day.

The records of the quantities of ground water used for industrial purposes are very incomplete, but it is believed that the pumpage by private industries is of the same general magnitude as that of the public water works, and the industrial use is probably increasing more rapidly than is public supply.

According to the Census reports, the acreage irrigated with water from wells was increased nearly 70 per cent from 1919 to 1929. Stimulated by the recent drought years and government aid, there has been further

great increase in the use of ground water for irrigation since 1929. Thus, in the seven Great Plains States—Nebraska, Kansas, Oklahoma, Texas, Wyoming, Colorado and New Mexico—the area irrigated with water from wells has been increased from 172,000 acres in 1929 to 559,000 acres in 1939.

Wartime Demands Upon Ground Water

Upon this situation of increasing ground-water use has suddenly been imposed the war, with its vast demands for water, not only for the military and naval establishments, but much more for the many large new war industries and the stepped-up activities of many old industrial plants. The quantities of water needed are of a higher magnitude than in the last war. Moreover, the demand is in large part for water from wells—to save time and materials, for strategic reasons, and because ground water is especially adaptable to cooling, manufacturing powder, etc. In viewing the situation one is almost appalled by the modern efficiency with which ground water is being recovered.

In the last fiscal year, the Geological Survey was consulted by the War and Navy Departments, the War Production Board and other agencies in regard to the available water supply at about 1,700 places, of which about 900 involved the use of ground water. A great effort has been made to avoid over-development in any place; but neither the Geological Survey nor any other agency has adequate information as to the total quantities of water that are being used, and no agency has control of the entire situation. Many establishments in the same area have started to pump ground water or have increased their rate of pumping without much regard for what other establishments are doing and without any central control. Two questions, therefore, present themselves: first, as to the sufficiency of the supply for the war needs; and second, as to its adequacy in the long run. The problem is one of determining whether the ground-water supply is perennial and reliable, or whether it is being exhausted, like the oil fields, with nothing but diminishing yields and salt-water encroachment in prospect.

U.S.G.S. Ground-Water Investigations

The United States Geological Survey undertook the investigation of the ground-water resources of the country soon after its establishment in 1879. Its first report on the subject, published in 1885, was by the eminent geologist Thomas C. Chamberlin (4), and related to artesian conditions as studied in Wisconsin. In the decade, 1890–1900, and in the first few years of this century, extensive ground-water surveys were made, chiefly in the Western States under the leadership of N. H. Darton; and the hydraulics

of ground water were studied by F. H. King and C. S. Slichter. In 1903, the Division of Hydrology was organized, and in 1908 its name was changed to the Division of Ground Water.*

For many years the investigations of the Ground Water Division were conducted on a meager scale, quite out of proportion to the importance and complexity of the subject. In the period since the last war there has, however, been a progressive increase in the funds annually made available for ground-water investigations. The demand came first from the states, which supplied funds for co-operation with the Ground Water Division. Since the fiscal year 1929, Congress has recognized these needs by making increased appropriations for the investigation of the water resources, but with the restriction that all except a small part of the funds can be used only for co-operation with state, county, and municipal governments, in which the contributions by the Federal Government can in no case exceed 50 per cent of the total expenditures. In the ten-year period immediately preceding the first world war, the expenditures for ground-water investigations by the Geological Survey and co-operating agencies averaged less than $20,000 a year; now the annual expenditure is about $500,000.

The Ground Water Division co-operates with the state geological surveys and other state agencies concerned with water resources, and in thirty-two states and the Territory of Hawaii, the co-operation is on a formal financial basis. Thus, there has been a close and constructive relation between the federal and state organizations in a more or less co-ordinated program, from year to year and from decade to decade, in the study of the ground-water hydrology and resources of the country. Such continuity and co-ordination have been very favorable to the development of effective technique in this highly specialized scientific field with its very practical applications, and to the selection and intensive training of capable geologists, engineers and physicists in the field. There has been no other similar opportunity for sustained and methodical study of the ground water in this country or in any other country in the world. At present this work is being conducted by a group of about a hundred federal and state employees stationed throughout the country.

Somewhat intensive investigations relating to the quantities of ground water that are perennially available were undertaken early in this century. In subsequent years the problems relating to the quantities of ground water were given systematic study, even though the subject was at that time commonly regarded as somewhat academic (5, 6).

Since that time much progress has been made in quantitative work and an extensive program has been developed for making periodic measure-

*The author began his service in this division in 1908 and has been in charge of it since 1912.

ments of water levels in about 7,000 observation wells and for obtaining correlative records of pumpage. About 300 of these wells are equipped with automatic recording apparatus.

The function of the Geological Survey with respect to the water resources is that of fact finding, which includes the interpretation of the data obtained with respect to the occurrence, head, quantity and quality of the ground water, the construction of wells of the types best adapted to the different terrains, the distribution of wells to obtain the largest supplies with the least interference and the possibilities of increasing ground-water recharge. The Geological Survey does not plan water works and does not generally make recommendations; it co-operates with the municipal and consulting engineers by giving them facts in regard to the water resources.

The co-operation of the superintendents and staffs of many of the municipal water departments and water companies in obtaining records of pumpage and of water levels in observation wells is very valuable and is much appreciated. Continuing records of pumpage and ground-water levels should be obtained for every public water works supplied from wells —for somewhat the same reason that all banks, whether large or small, keep current records of their resources and liabilities. The Geological Survey and the related state agencies are eager to co-operate with water works men in obtaining good and continuing records of this kind. A comprehensive survey of the ground water that is being used for war purposes has recently been undertaken. In this project the co-operation of Army, Navy and other federal officials and of the personnel of many industries will also be needed.

Functioning of Ground-Water Reservoirs

The fundamental fact about ground water is that it occurs in great widespread subterranean reservoirs, many of which have large storage capacities. These natural reservoirs are irregular and intricate in their construction, but they can be accurately mapped and their structure can be determined by adequate geologic study supplemented by test drilling. The hydraulics of these subterranean reservoirs is also intricate, with respect to the intake, head, movement, storage and discharge of their waters, and it involves principles of physics which have little or no significance in the hydraulics of surface waters. The waters of these reservoirs, however, obey rigorously the laws of fluid mechanics. Therefore, within limitations imposed by the irregularities of the rock formations and of the weather, it is possible to determine their annual recharge, perennial yield and storage capacities (7, 8). Moreover, the efficient and beneficial operation of the reservoirs can be accomplished by the practical application of the knowledge developed by these scientific methods of investigation (9).

A fundamental question in regard to any ground-water development is that of how much of the pumpage or artesian discharge is taken out of storage and how much is supplied by intake or recharge from the surface. The rate of recharge depends largely upon the size of the intake area, the permeability of the surface formation in the intake area and the amount and distribution of the precipitation. The distribution of the precipitation is particularly important. Thus, winter rainfall in California produces much more ground water than a like amount of rain that falls in New Mexico in the summer, when the water is held by the dry soil and most of it is returned quickly to the atmosphere.

Various methods are available for estimating the recharge; for example, that based on the rise of the water table and the effective porosity, or specific yield, of the saturated material (6). The recharge, however, fluctuates from year to year even more widely than does the precipitation, because the vegetation gets the first chance at the water from rain and snow, while the subterranean reservoirs get only the surplus. Thus, records covering a period of years are required to determine the approximate average recharge. In some places, the rate of recharge can be greatly increased by pumping, because a reservoir that is full cannot take in more water.

The water that seeps into a subterranean reservoir may be in storage a very long or a relatively short time. Where there are no wells, the water is eventually discharged through springs and other effluent seepage and by evaporation and the transpiration of plants where the water table is near the surface (10, 11). The flow of streams in fair weather is the retarded overflow of the natural reservoirs. Therefore, the stage of the water table, as indicated by the water levels in observation wells of a certain type, is being given critical study in some areas, with a view to forecasting the low flow of streams in summer and fall for water supply and generation of power (12).

Wells that tap natural reservoirs with large hold-over storage furnish water supplies that are secure from drought and are available to carry peak loads and to supplement surface supplies in times of drought; but, if the long-term average rate of pumping exceeds the available long-term average recharge, there will come an inevitable time of reckoning, when the storage is depleted, the water levels drop below the level that is practicable for pumping and salt water may move in.

Many of the largest ground-water supplies come from artesian reservoirs in which the water must move long distances from the intake areas to the wells. There the maximum perennial supply may be determined, not by the recharge, but by the capacity of the aquifer to transmit water. In recent years, under the leadership of C. V. Theis and L. K. Wenzel, notable

progress has been made in the theoretical and field study of the hydraulics of ground water, under non-equilibrium as well as equilibrium conditions. Practicable methods are now in existence for computing coefficients of transmissibility and for determining the cones of depression with specified rates of pumping for different periods, and hence for determining the interference of wells and the proper spacing of wells (13, 14, 15).

In May 1941, at the Washington, D.C., conference of the Ground Water Division, thirty papers were presented on salt-water problems in different parts of the country and on the available methods for studying salt-water encroachment. This survey showed that, as yet, damage by salt-water encroachment has been relatively local and restricted, but that with the present trend toward over-development there is danger of more serious damage in the not very distant future.

Results of U.S.G.S. Investigations

The quantitative ground-water investigations have shown such a great variety of results in different areas that they can not be briefly summarized. Some subterranean reservoirs have very large annual recharge; others very small. In some, the rate of recharge can be greatly increased by pumping; in others not. Some have very large quantities of water in storage and wells of large yield, but only meager recharge, etc. A few examples, largely from unpublished data furnished by members of the Ground Water Division conducting investigations in various parts of the country will, however, throw some light on the subject.

Across the northern part of the United States, from the Atlantic to the Pacific, have been deposited water-bearing sands and gravels of glacial origin that supply perhaps 2,000 public water works and a vast number of private establishments. These deposits are as a rule readily recharged, but they are irregular and, in any area, the wells must be properly distributed to get the maximum supply. In many areas there is local over-development, although large unused supplies exist elsewhere in the area.

Outstanding is the deposit of glacial gravel at Spokane, Wash., where large dug wells yield 10 mgd. for each foot of drawdown and where the underflow approximates 500 mgd. Long Island is also noteworthy for its large perennial supply. In the western part of the island, pumpage from the glacial sands of about 100 to over 200 mgd. since 1904 has been essentially all from recharge, except a small proportion from storage in the excessively pumped area in Brooklyn. In the eastern part of the island a considerably larger supply remains underdeveloped.

The Indianapolis and Cincinnati areas serve as examples of productive glacial deposits locally developed to the limit. For years in the Indianapolis area there has been heavy pumping from sand and gravel

deposits and from the limestones that underlie the drift, and only a small part of the water has been taken from storage. With the aggregate pumpage from wells now stepped up by the war to more than 50 mgd., an acute problem of overdevelopment has been created in parts of the area, although at some distance from the city there are still large unused supplies. In the Cincinnati area (Hamilton and Butler Counties, Ohio), the aggregate pumpage from wells averaged about 75 mgd. in 1940. In the Mill Creek Valley in that area, the pumpage in 1939 averaged about 13 mgd. and the recharge about the same. Since then the rate of recharge has been less and, because of the war industries, the rate of pumping has been greatly increased. Thus, the supply is no longer adequate to meet the demands, and water is now to be piped into Mill Creek Valley from wells in the Miami Valley.

In the Mississippi Valley region many of the public supplies are obtained from wells in limestone and sandstone. Where these aquifers lie near the surface, they are readily recharged, functioning somewhat like the glacial sands and gravels. Many of the oldest water works in this region have, however, long obtained their supplies from deep wells in the artesian parts of the sandstones, which are quite unaffected by even the severest droughts, but in which have been developed great cones of depression in the artesian head, with increased pumping lifts.

The Atlantic and Gulf Coastal Plain, extending from New England to the Rio Grande, has many productive aquifers, a large number of water supplies developed from wells, and numerous problems of both quantity and quality of water, including threats of salt-water encorachment, with actual encroachment in a few areas. Several years ago the author made a rough estimate that there were 1,400 public water supplies derived from wells in the Coastal Plain, but the actual number at present is probably substantially greater.

In the coastal belt from Savannah, Ga., to Jacksonville, Fla., all municipal supplies and some very large industrial supplies are derived from wells that draw from productive artesian limestone. The total withdrawal, in this belt, by artesian flow or pumping, is about 180 mgd. Pumping of about 32 mgd. at Savannah has produced a cone of depression in the artesian head that extends more than 30 ft. below sea-level. Although the artesian water is still entirely fresh, the possibility exists that sea water may be percolating toward the wells. In contrast, at Brunswick, Ga., further down the coast, the withdrawal of artesian water is also at the rate of about 32 mgd., but, owing to the greater permeability of the limestone, there is only a slight cone of depression and the head is still nearly 50 ft. above sea-level. Until recently the public supply of Jacksonville has been derived entirely from natural flow.

The water supplies for San Antonio, Tex., are also obtained from cavernous limestone under artesian conditions. Something of the problems of conservation and control in this area can be appreciated from the fact that recently an artesian well, 1,032 ft. deep and 24 in. in diameter, with a natural flow of about 24 mgd., was brought in.

In the Miami area, in southeastern Florida, large perennial supplies are available from surficial limestone under water-table conditions. Because of the extreme permeability of the limestone, however, the water table is only a little above sea-level, and with slight further lowering, by drainage ditches or pumping, sea water may penetrate the formation.

Artesian conditions similar to those at Savannah exist in the 800-ft. sandstone at Atlantic City, N.J., and in the sands underlying Houston, Tex. In both places the cone of depression in the artesian head extends considerably below sea-level and there are overlying or underlying beds of salt water. In six areas in the Coastal Plain of Texas, an aggregate of 215 mgd. was withdrawn from wells in 1940, of which about 80 mgd. was pumped in the Houston-Pasadena Ship Channel district. The water supplies of the Memphis area are also obtained from sands under artesian conditions. There, pumping at the rate of 50 mgd. or more has produced only a moderate cone of depression and there is apparently no danger of salt-water encroachment.

The Great Plains are underlain by extensive outwash produced by the uplift of the Rocky Mountains. The water-bearing sands and gravels of this outwash are mingled with the glacial outwash and extend to the Mississippi River and the Gulf of Mexico. In some places these sands and gravels have large recharge, but in others very little. In parts of the Arkansas Valley there has been heavy pumping for many years without depletion. In this valley, in the westernmost five counties in Kansas, the water table has risen recently in spite of pumping at a rate averaging 60 mgd. throughout the year. On the High Plains of Texas the pumpage in 1940 averaged about 200 mgd., but the water came chiefly from storage, with slow but sure decline of the water table. There, as in some other areas, water supplies for certain war industries that require large quantities are being planned, not on recharge, but on storage adequate for at least five years. Since September 1940 a new soft-water supply for Wichita, Kan., has been pumped from twenty-five widely spaced wells, at a rate of somewhat over 10 mgd., and excellent records are being obtained of the current pumpage and fluctuations of the water levels.

The valley fill in the western mountain region yields water to wells in quantities running to billions of gallons per day—chiefly for irrigation, but also for public and industrial supplies. In the Southern Coastal Basin of California the average withdrawal through wells is between 500 and 800

mgd.; in the Santa Clara Valley (south of San Francisco) it is more than 300 mgd.; in Arizona it amounts to several hundred million gallons daily; and in Utah it is about 200 mgd., etc. Most of this water is replaced by recharge but some important areas, such as the San Joaquin Valley and parts of Arizona, have been seriously overdeveloped. Artificial recharge is practicable in many areas and has been notably successful in the Santa Clara Valley and locally in the Southern Coastal Basin of California.

In the El Paso area the recharge has been estimated to average 10 to 15 mgd., but consumption now greatly exceeds that rate. Fortunately, there is a large reserve of good water in storage which can meet the needs for a considerable period of years and will allow orderly development of an additional supply from the Elephant Butte Reservoir.

Salt Lake City, threatened with serious water shortage in 1934, in a few weeks developed a supply of about 30 mgd. from wells in the valley fill. These wells are generally held in reserve and they give the city exceptional security and capacity to meet new and unforeseen needs. Ogden, Utah, on the other hand, gets its supply of about 10 mgd. from a relatively small artesian reservoir whose storage is heavily drawn upon each summer but is generally fully replenished in the following spring.

In Hawaii very large supplies are obtained from the lava rocks—for Honolulu, the irrigation of sugar cane, and military, naval and other uses. In 1940, the pumpage from wells averaged 350 mgd. on the Island of Oahu and 185 mgd. on the Island of Maui. Wells of the "Maui" type yield up to 40 mgd. The salt content of the water has increased in many wells, but it can largely be controlled by regulating the rate of pumping. On the other hand, there remain areas on these islands where large quantities of ground water still await development. Here, too, it should be mentioned that the great quantities of water in the lava rocks of northwestern United States also remain largely unused.

Necessity for Legal Control

It has been pointed out that the efficient and beneficial operation of the subterranean reservoirs can be accomplished by the practical application of the knowledge developed by scientific methods of investigation. It can be fully accomplished only through control by competent governmental agencies with adequate and wisely defined legal powers. The paper on the legal control of the use of ground water presented by D. G. Thompson and A. G. Fiedler at the New Orleans meeting of the American Water Works Association in 1938 (16) aroused much interest, showing that the water works profession is keenly aware of the need for legal control. In a few states more or less adequate laws have been enacted and, notably in New Mexico and Utah, they have been effectively and beneficially enforced by

the state engineers, chiefly for irrigation use. In many other states, in different parts of the country, proposed laws are under consideration. It is recognized that this is an exceedingly difficult problem in several respects. Nevertheless, the time has come for the state legislatures to proceed with the enactment of ground-water laws, and the laws should generally be based on the principle of appropriation for beneficial use, as has been recommended by the National Land Use Planning Committee and by a committee of the Association of Western State Engineers.

The Roswell Artesian Basin, in New Mexico, may be cited as the country's leading example of equitable and effective legal control and conservation of ground water—accomplished as the result of thorough investigation, careful legislation, wise judicial decision, conscientious administration by the State Engineer and intelligent co-operation by the local population.

Future Conservation and Development Program

An outline of the future program for the conservation and development of the ground-water supplies of the United States should include four points:

1. The study of ground-water hydrology and its application to specific areas should be continued and intensified, so that exact and reliable information will be available in regard to the ground-water resources of every part of the country.

2. The superintendents of public water works should obtain continuing records of the pumpage from each well or group of wells and of the fluctuations of the water levels in properly selected observation wells. They should co-operate with the U.S. Geological Survey and the appropriate state agencies in obtaining these records, so that the measurements will be made under the proper conditions and so that the records will be compiled and preserved and will be given scientific study.

3. The engineers in the field of water supply and also the geologists who undertake to serve as consultants should give serious study to the principles of ground-water occurrence and to the techniques of its development. It is high time that the engineering schools and the departments of geology in the large universities gave thoroughly technical courses in ground-water hydrology and ground-water hydraulics.

4. With adequate knowledge of the ground-water resources must come effective legal control in every state. In the present war emergency, heavy drafts on the ground water in storage are unavoidable, but everyone must be on the alert to prevent disastrous depletion. In the future there must be an insistence upon control which, with full conservation and development, will make ground-water supplies perennially secure.

References

1. MEINZER, O. E. Importance of Ground-Water Supply. W.W. Eng., **91:** 1086, 1139, 1157 (1938).
2. MEINZER, O. E. Notable Improvements in Ground-Water Development. Eng. News-Rec., **110:** 750 (1933).
3. ANON. Inventory of Water Supply Facilities. Eng. News-Rec., **123:** 414 (1939).
4. CHAMBERLIN, T. C. The Requisite and Qualifying Conditions of Artesian Wells. U.S. Geol. Survey, 5th Ann. Rept. (1885); p. 125.
5. MEINZER, O. E. Quantitative Methods of Estimating Ground-Water Supplies. Geol. Soc. America Bul., **31:** 329 (1920).
6. MEINZER, O. E. Outline of Methods of Estimating Ground-Water Supplies. U.S. Geol. Survey, Water-Supply Paper 638c (1932).
7. TOLMAN, C. F. *Ground Water.* McGraw-Hill, New York (1938).
8. *Hydrology: Physics of the Earth.* McGraw-Hill, New York (1942); Vol. 9, see chapter entitled "Ground Water," by O. E. MEINZER AND L. K. WENZEL.
9. MEINZER, O. E. Progress in the Control of Artesian Water Supplies. Eng. News-Rec. **113:** 167 (1934).
10. MEINZER, O. E. Plants as Indicators of Ground Water. U.S. Geol. Survey, Water-Supply Paper 577 (1927).
11. WHITE, W. N. A Method of Estimating Ground-Water Supplies Based on Discharge by Plants and Evaporation From Soil—Results of Investigations in Escalante Valley, Utah. U.S. Geol. Survey, Water-Supply Paper 659a (1932).
12. MERRIAM, C. F. Analysis of Natural Fluctuations in Ground-Water Elevations. Am. Geophys. Union Trans. (1942) (*in press*).
13. THEIS, C. V. The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage. Am. Geophys. Union Trans. (1935); p. 519.
14. THEIS, C. V. The Significance and Nature of the Cone of Depression in Ground-Water Bodies. Econ. Geol., **33:** 889 (1938).
15. WENZEL, L. K. AND FISHEL, V. C. Methods for Determining Permeability of Water-Bearing Materials, With Special Reference to Discharging-Well Methods. U.S. Geol. Survey, Water-Supply Paper 887 (1942).
16. THOMPSON, D. G. AND FIEDLER, A. G. Some Problems Relating to Legal Control of Use of Ground Water. Jour. A.W.W.A., **30:** 1049 (1938).

Midwest Problems—Charles B. Burdick

AT PRESENT the business of war is the chief consideration of every citizen. Water must be supplied to meet the requirements of the Army at new locations and existing supplies must be expanded. The most vital necessity in connection with these supplies is speed of construction and certainty of development. In many instances ground water furnishes this means for quick development, its comparatively low temperature making it especially advantageous for certain industries, particularly for the manufacture of explosives.

It is the purpose of this discussion to consider ground water developments in the Midwest region, i.e., the area roughly defined as lying between

the Canadian boundary and the Gulf of Mexico, and the Appalachian and Rocky Mountain ranges. This is a well watered country, except at the westerly borders, with rainfalls generally varying from 24 to 48 in. per annum.

Problems of Development

Within the area described ground water in the limited amounts required for agriculture can be obtained upon nearly every square mile, and, therefore, will not be discussed. It is with the development of larger supplies, ranging from a million gallons per day and upward, that more favorable conditions must be present and that problems arise. The magnitude of the water supplies required for the munitions industries compares to that required by cities of from 20,000 population to more than ten times that figure, i.e., water delivered at average rates of from 2 to more than 30 mgd., with peaks roughly comparable to the variations incident to municipal supply. Even the smallest of these supplies require exceptionally good ground-water conditions for successful development.

In their development, there must be a sufficient gathering area to collect the necessary seepage into the soil, strata of granular materials to transmit the water to the place of development and capacious beds of granular materials well below the ground-water plane through which the water may be taken for development in the general locality of use by the various means adapted to the capture of the water.

In regard to the gathering ground, only very exceptional conditions would permit 12 in. of rainfall per year, i.e., 1 in. per month, to enter the subsoil beyond the recapture of surface vegetation. Since 1 in. per month is equivalent to about 560,000 gpd. per sq.mi., it will be seen that a supply of 10 mgd. from upland sources must be replenished by not less than 20 sq.mi. of gathering ground under the most favorable circumstances. Under ordinary conditions the area required is several times this figure. The situations where such large supplies can be obtained in the Midwest region or, for that matter, anywhere else in the United States, are quite exceptional.

While surface soils of very poor permeability serve to transmit important replenishment to the ground waters stored in the soil, the ability of the underlying strata to transmit the water for material distances is only possible where granular materials or rock crevices of comparatively large water capacity exist. Granular transmission media must approximate the grain size commonly used for mechanical filtration. When it is borne in mind that the velocity in such media varies approximately as the square of the grain size and approximately as the square of the void space in the transmission media, the importance of comparatively thin strata of very coarse gravel is emphasized. Such figures also emphasize the fact that

the finer of the sands, say 0.1 to 0.2 mm. in effective size, are of comparatively little use unless the thicknesses of the strata are very great, and indicate the practical impossibility of transmitting water for considerable horizontal distances through sands and gravels that contain even a nominal percentage of clay particles.

Large Developments in the Midwest

The localities where large developments have proved practicable are so few that a list, with essential facts, is included here:

Texas Coastal Plain

This is a very extensive sand bed, upland fed, in north-central Texas, which slopes toward and into the Gulf of Mexico. The average draft by the city of Houston is from 25 to 30 mgd. and industries independently develop about 50 mgd. Galveston is also supplied from this source as are many other smaller cities. San Antonio, further west, has a similar gulfward sloping source. These supplies are taken from tubular wells.

Baton Rouge District

Supply is taken from very deep alluvial deposits in the Mississippi delta, probably largely upland fed. These deposits, largely sands, are over 2,000 ft. thick at Baton Rouge. The city use averages about 5 mgd. Industries, largely recent and incident to the war, develop not less than 50 mgd. This supply is artesian in character and formerly supplied the city by gravity.

Memphis, Tenn.

The city supply is taken from sands fed by upland sources, formerly artesian, and developed from tubular wells. The average use exceeds 20 mgd. and industries separately develop nearly as much.

Ohio River

A large war industry near Louisville has developed about 70 mgd. from wells of a special type which tap the alluvial sands adjacent to, and possibly under, the river. This locality marks the south end of glaciation with the probability of a buried river channel. Increasing water temperatures indicate infiltration from the river.

Ohio Fields

Dayton, with 211,000 population, Hamilton, with 51,000 population, and other smaller places are supplied from the sand beds on the flood plain of the Miami River, probably largely fed from the bordering glacial

hills. Springfield (71,000 population) is similarly supplied from infiltration galleries in the flood plain of a small tributary. Between Hamilton and the Ohio River not less than 66 mgd. are developed by cities and industries. A 22-mgd. additional supply is now being developed. Canton, in northeast Ohio, (population 109,000) develops its water from a glacial valley.

Michigan

This state is characterized by very low bed-rock heavy glacial deposits, largely sandy, somewhat hetergeneous, with many relatively small groundwater developments. Lansing (population 79,000) and Kalamazoo (population 54,000) are thus supplied, probably largely, from upland morainic gathering grounds; and South Bend, Ind. (101,000 population) is similarly supplied.

Indianapolis

This city takes 17 mgd. more or less continuously from limestone wells underlying the sands of the White River valley and has an emergency supply which has developed 11 mgd. for a short time from the sands which overlie this rock and are probably the source of the rock supply. The main source of the city (387,000 population) is direct from White River. The industries of the city have developed separate supplies in total probably equal to the city supply from the same underground sources.

Illinois-Wisconsin Artesian Field

An extensive bed of sandstone, usable through wells 1,000 to 2,000 ft. deep all over northern Illinois and southern Wisconsin, furnishes the supply for all cities over an area about 250 by 150 mi. in extent. The gathering ground is ample, but the transmission lenses make it difficult to draw more than 5 or 10 mgd. into a 1- or 2-sq.mi. area, and falling water levels accompany such a draft. A large industrial development has been used for many years at the Chicago Stock Yards. A large war industry development has been made southwest of Chicago. In this general region moderately large supplies are developed from the shallow sands of the Mississippi River, from the Illinois line north, and much larger supplies could be developed if needed. At the mouth of the Missouri River industries now take very heavy drafts and there are sizeable supplies at Lincoln, Neb., Sioux City, Iowa, and Eau Claire, Wis., all from shallow river bed sands.

Other developments of ground water in the Midwest region are of moderate size only, except two, which are described in some detail because the circumstances surrounding them are rather unusual.

River Bed Infiltration

Most rivers in the glaciated area of the country flow through valleys between bordering hills which contain gravel deposits of considerable magnitude. Where the sands and gravels are clean and reasonably extensive, very large supplies of water can be developed, but such opportunities are comparatively rare.

Under natural conditions the soil water adjacent to the stream pitches toward it, indicating the natural flow of ground water toward the stream under the adjacent bottoms. Where the river flows on such a sand and gravel bed, a well sunk in the river itself will show a water level above the water surface in the river, indicative of the lost head in the seepage from the underlying sands into the river stream.

When a large supply is developed adjacent to such a river the natural conditions are changed, in that the surface of the ground water is drawn down adjacent to the development. When this occurs the natural conditions prevailing are reversed and the water in the stream tends to flow into the underlying water-bearing stratum, in the process of which it becomes quite thoroughly purified because the granular river bed material is relatively fine in texture. Any filter will tend to plug up in the course of time. Mechanical water filters taking water at about 125 mgd. per acre are usually washed every day or two. To be effective river bed filtration must be operated at very low rates, i.e., at $\frac{1}{500}$ of mechanical filtration rates, more or less. When a river bed filtration area is thus operated it will serve for some time; it can be operated continuously only if the river bed is cleaned periodically by the scouring action of flood flows.

Infiltration Supply at Des Moines

An example of a supply primarily from river bed infiltration is furnished by the municipal supply at Des Moines, Iowa. A few facts related to this supply will be worth noting in view of the comparative rarity of the conditions that make it possible to study such a case in detail.

The Des Moines supply is taken from the sands closely adjacent to the Raccoon River. This stream flows through an ancient valley about a mile in width, cut a little more than 100 ft. deep between the bordering hills. The bottom of the valley consists of relatively impervious clays and shales, the clays extending up to the tops of the side hills, thus completely enclosing the river valley and preventing the ingress of ground water from the bottom or from the sides of the valley. With the recession of the glaciers, the bottom of the valley was paved to a depth of 20 to 40 ft. with relatively coarse sand interspersed with gravel. The river now meanders back and forth on the top of this sand bed, the immediate banks of the

present stream consisting of relatively impervious clay silts to a height of 15 to 25 ft. above the low water stream level.

The supply is developed from a collecting gallery, essentially a horizontal well, which is located in general about 200 ft. inland from the river bank and which at the present time, is about three miles in total length. The water is taken by the high lift pumps which draw from a suction well connected to the gallery system, thus depressing the ground water in the galleries, generally about 5 ft. below the water surface in the river. The system now produces an average of about 14 mgd. over the whole year; the rate is about 20 mgd. in the summer season, with hourly peaks up to 30 mgd. The general arrangement of the supply is shown in Fig. 1.

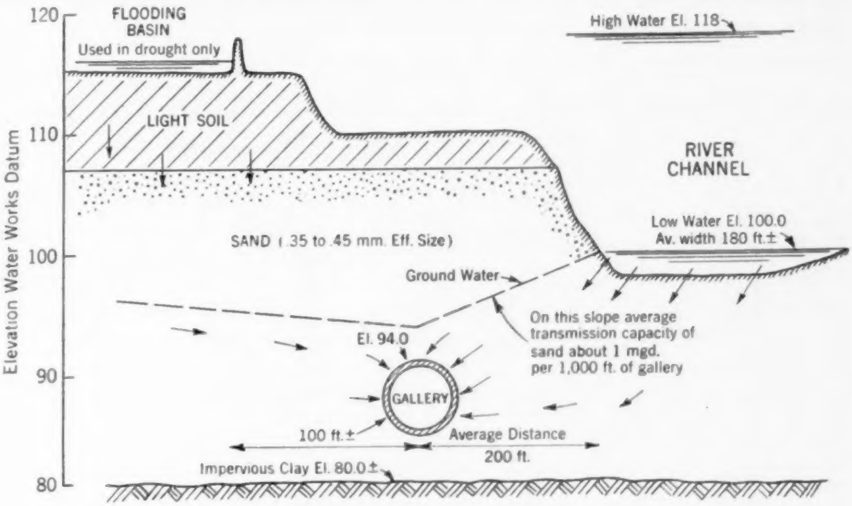

FIG. 1. Details of Des Moines, Iowa, Infiltration-Gallery Supply

This supply has been developed gradually, from about 4 mgd. in 1908, on a predetermined program under which the river bed is subjected to an average infiltration rate approximating $\frac{1}{4}$ mgd. per acre.

The river bed has been found to vary widely in its ability to take infiltration; so, to handle the situation effectively, the flooding of the ground on the land side of the gallery system is used to supplement the infiltration from the river bed. Upon the average, about one-third of the supply developed is thus secured from the flooding of land. Periodically a good flushing flood will clean the river bed to such extent that practically no land flooding is necessary for as much as a year at a time. Table 1 shows the percentage of the total pumpage that has been obtained from land flooding during the past twenty-one years, since accurate records have been kept.

The land-flooding basins are simply relatively flat lands enclosed by dikes, 2 or 3 ft. high, without grading or removing the sod. The water passes downward through from 10 to 20 ft. of clay silt, into a 10- to 20-ft. stratum of coarse sand, which, like a filter underdrain, leads the water to the gallery. The edges of the beds are about 100 ft. from the gallery. Filtration rates generally are less than ½ mgd. per acre. Beds are scraped at intervals of one to three years. Winter conditions are no detriment.

Essentially this source of supply has been used for the entire supply of the municipality for about seventy years, although the fundamental principles relating to it were not well established until 1908. The quality of water and its cost are about the same as in mechanical filtration, when operating expenses and all fixed charges including a large land acreage are taken into consideration.

TABLE 1

Percentage of Total Annual Pumpage Developed From Land Flooding at the Des Moines, Iowa, Municipal Water Works

CALENDAR YEAR	PERCENTAGE OF TOTAL PUMPAGE FROM LAND FLOODING	CALENDAR YEAR	PERCENTAGE OF TOTAL PUMPAGE FROM LAND FLOODING
1921	33	1931	58
1922	35	1932	1.4
1923	32	1933	5
1924	34	1934	52
1925	34	1935	50
1926	36	1936	32
1927	14	1937	48
1928	7	1938	49
1929	13	1939	44
1930	20	1940	59
		1941	31

Shallow Ground-Water Supply at Peoria

A remarkably capacious shallow ground-water supply exists in the valley of the Illinois River at and adjacent to the city of Peoria. Within the area paralleling the Illinois River, comprising the water front of the city from a point a few miles north of the city limits to a point immediately below Pekin, a river length of about twenty miles, about 70 mgd. are taken from the ground, including the supplies to the municipalities. About 80 per cent of this water is taken by some 112 industrial users. The supply is developed from tubular wells from 40 to 120 ft. in depth below the surface of the river. In and immediately adjacent to the city, about 52 mgd. are developed, of which about 12 mgd. are developed by the Peoria Water Co. for supplying the city.

This is a situation in which, although underlying the river and its extensive expansion known as Peoria Lake, the water-bearing sands and gravel also extend, to a greater or less extent, under and inland from the hills northeastward and northwestward to the places of principal water development. In this case it seems probable that the source of the water is partly natural ground water seeping downward through relatively impervious clays in the highlands and partly infiltration from the stream bed which is closely adjacent to the localities of heaviest development, where the ground water is drawn down from 10 to nearly 50 ft. below the water surface in the river.

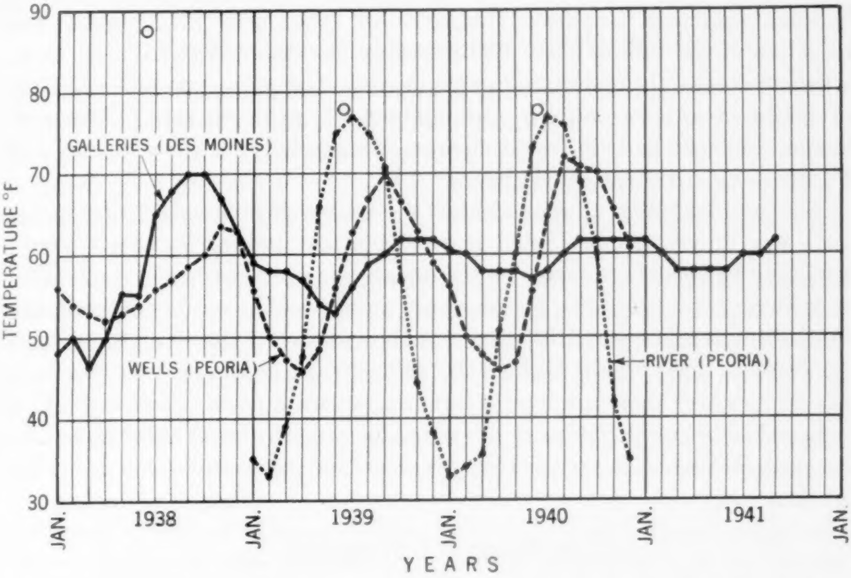

FIG. 2. River and Ground-Water Temperatures at Peoria, Ill., and Infiltration-Gallery-Water Temperature at Des Moines, Iowa, 1938–41

(NOTE: Circles indicate average air temperature of warmest month.)

This general source of supply has been in use in gradually increasing amounts for more than sixty years, although the total development has not increased much, if any, during the past eight years due to receding ground-water levels. The ground-water level has been depressed some 20 ft. in the past eight to ten years.

An important reason for the use of ground water at Peoria is its favorable temperature, varying with the season of the year from about 52° to 62°F. Figure 2 shows the temperature variations of the ground water and the river water from month to month during a four-year period.* For pur-

* Data furnished by the Illinois State Water Survey.

poses of comparison, the monthly variation of the water temperature at Des Moines, Iowa, as developed by the infiltration supply has been plotted on the same graph.

The subsoils apparently have a tendency to absorb the heat in the ground water in some proportion to the flow of ground water. It is noted that the temperature lag in the ground water at Peoria as compared to the river water is a matter of about three or four months. At Des Moines where practically all the water comes from infiltration, the lag is only about half as great.

The possibility of replenishing the ground water at Peoria through artificial means, by subjecting suitable areas to the flooding of river water through pumping, has been studied. An experiment made under the direction of the Illinois State Water Survey has shown that a certain area, where the top of the underlying water-bearing stratum is exposed, is capable of taking river water at the rate of about 27 mgd. per acre. This rate would obviously have to be cut down very materially for effective sanitary results in a permanent development.

The practicability of replenishing the underlying water-bearing materials was amply demonstrated and calculations indicated that it would probably be feasible to replenish the underlying sands with cold river water to such an extent that the Peoria development could run on storage in the underlying sands during the season of the year when the river water temperature is unfavorably high. The difficulty of accomplishing this in a situation where there are over a hundred separate users is evident. It is believed to be possible to carry out a feasible project of cold water replenishment if and when a satisfactory organization for co-operation has been worked out.

Problems of Investigation

Nearly all ground-water developments have been based upon trial and error. It has been possible in comparatively few instances to give the situations enough study to formulate possibilities in regard to ultimate development. The fundamental principles are easy to understand. The difficulties arise because the underlying facts are beneath the ground surface and can only be developed by painstaking and expensive sampling methods. In some situations, like that at Des Moines, the facts are comparatively easy to ascertain. Where there is a fair definition of the facts, a program of development can be followed successfully.

It is the history of nearly all ground-water projects that continuing development and continued use is accompanied by a recession in ground-water levels. Obviously some depression must be experienced in order to

bring ground water to a central location. Even with a constant draft, good facilities for water collection and good facilities for the transmission of the water to the place of development, levels will continue to fall unless the source of the water is equal in amount to the draft from the collecting system.

The development of water supplies for the present war industries is necessarily a rush job and it must be certain in its results. There is no time for the extensive investigation of unknown conditions. Generally the only practicable thing to do under the circumstances is to utilize the ground waters that have been disclosed by municipalities. In all cases where temperature is not vital, however, visible sources should be utilized.

Pacific Coast Problems—Samuel B. Morris

IN THE present national emergency, factories, cantonments, military posts and greatly expanded local communities in many cases have found the answer to their water problems in ground-water supplies. This is particularly true in the south Pacific Coast and Great Basin areas where surface streams are so unreliable and where prior rights have completely used all available surface supplies.

Sometimes surface storage is not practical for the immediate future as the first year or two or several years may be drought years with no water available for storage. On the other hand, ground-water supplies in many areas may be available for the war period of a half-dozen years, irrespective of the uncertainties of replenishment. It is always highly desirable, however, that some knowledge of the quantity of water in storage, replenishment, the total area which will be affected and, of course, the quality of the water, be known.

Several of the very large military and industrial establishments are wholly dependent upon ground water. Others have been more rapidly initiated with ground-water supplies or use such supplies to supplement surface or public water supplies. There have been some difficulties, and not a little added cost, in adapting the long distance Washington standards and procedures to the local ground-water problems and to the experience and equipment of local drillers. Size, type and weight of well casing, character of screen or perforations, type and dimensions of well shoe, drilling tools, size and type of drilling rig, standard or rotary drilling method with selection of muds and classification of well log are all matters of selection based upon knowledge of ground-water geology of the particular region to be drilled. Well drilling is an art in which science can be of great aid. Local experience of drillers is invaluable but must be weighed by sound technical knowledge of engineers with broad experience.

Hydrology of Pacific Coast Area

Little can be said in generalization of the climatology, hydrology or ground water in the Pacific Coast states. Annual rainfall varies from more than 100 in. in the Olympic Mountains and along the crest of portions of the Cascades and the Sierras to as little as 10 in. east of the Cascades in Central Washington and to less than 5 in. in the deserts of Southern California, Nevada and Arizona. Locally there is generally an increase in rainfall with elevation up to 6,000 to 10,000 ft. There is one common factor, however, in the states bordering on the Pacific—the summer months are almost devoid of rainfall. This factor has made regulatory storage particularly important in the West. Unregulated surface streams in the late summer and fall become very low; in fact, in many areas, particularly in the Southwest, they actually cease to flow.

It may be of interest to illustrate this situation with actual data on the San Gabriel River at Azusa. This stream drains 214 sq.mi. of mountainous country varying in elevation from 750 to 10,800 ft. A record over 45 yr. shows the following runoff:

	Cubic Feet per Second	*Percentage of Mean*
Mean flow	180	100
Peak flow	94,000	52,200
Minimum flow	3	1.67
Maximum year	567	315
Minimum year	13	7.23
Maximum 12-yr. average	256	142
Minimum 8-yr. average	63	35

Particular attention is directed to the variation in runoff in periods as long as 10 yr. No reasonable average flow can be secured for periods shorter than 20 yr.; in fact, this is entirely too short. Accurate continuous records of rainfall at Los Angeles began in 1877, but estimates have been extended back as far as 1769 by study of crop reports of the Spanish padres and other early sources. These records reveal a drought as long as 43 yr. The average rainfall at Los Angeles is 15 in., but from 1883–84 to 1892–93 the 10-yr. average was 20.25 in. and from 1893–94 to 1903–04 the 11-yr. average was 11.36 in. per year. Other mountain streams in the Southwest have even greater departures from normal than the San Gabriel River.

Areas of Alluvial Deposits

In the Metropolitan Area about Los Angeles, the South Coastal Basin contains 1,400,000 acres of habitable area. There, 6 per cent of the arable land and nearly 50 per cent of the population of California are found, but only 0.6 per cent of the natural streamflow.

Fortunately block-faulting has provided a series of ground-water basins which together constitute the South Coastal Basin with a surface area of 835,600 acres. The State Division of Water Resources has estimated the underground capacity of a 100-ft. zone, 50 ft. above and 50 ft. below the January 1933 ground-water table as 6,861,000 acre-ft. No present useful surface storage in the United States, except Lake Mead, is as great. The surface storage of 150,000 acre-ft. on the San Gabriel River has cost more than $40,000,000.

Along the coast of California from the Mexican border to San Francisco, many of the missions established by the Spanish friars at the time of the American Revolution were located near *cienegas* or perennial streams flowing from low areas of ground-water basins. The Missions of San Gabriel and Los Angeles were two of them.

In San Diego County the more important water supplies are the result of surface storage. Hold-over storage for as long as 10 to 12 yr. is required, resulting in the loss by evaporation of approximately 50 per cent of the available water supply. Ground-water storage generally has the advantage of much lower losses, but the ground-water storage along the valleys of the Tia Juana, San Diego, San Luis Rey and San Juan Rivers is small in comparison to those of the South Coastal Basin in Los Angeles and Orange Counties. Ground water is the principal supply for the citrus orchards of Southern California.

Northward there are important ground-water supplies along the Santa Clara and Ventura Rivers, the Santa Ynez and Santa Maria River Valleys, the Salinas, Pajaro and Santa Clara Valleys. The large areas of truck gardens and deciduous fruits are irrigated almost entirely with ground water.

The largest areas irrigated by ground water are in the great Central Valley of California traversed by the Sacramento and San Joaquin Rivers. There, the use of electrically driven pumps constitute such a large load that the peak demand on the Pacific Gas and Electric Company's million kilowatt system is in the summer rather than in the winter. In the South San Joaquin area below Fresno water pumped from wells provides the sole source of water supply for half a million acres and a supplementary supply for half a million more, in all a million acres of farm lands and many cities dependent upon ground-water supply.

Most of the ground-water supplies of California are the result of the large detrital filled valleys. Streams emerging from the adjacent mountains discharge across the debris cones into the valleys. Generally the debris cones are the better absorption areas, but this is not always the case. Frequently lacustrine or marine deposition has resulted in extensive artesian caps in the lower valleys, particularly in the interior valleys of California,

Arizona and Nevada. Extensive ground-water areas exist in Coachilla Valley, Antelope Valley, and adjacent to the Mojave River in otherwise truly desert areas.

Frequently rainfall on the valley floor and return water from irrigation are important sources of ground-water replenishment that have been underestimated or overlooked. In fact, in many large irrigated areas, water-logging of lands has made extensive drainage problems. In some regions, such as the Salt River Valley in Arizona, drainage by deep-well pumps has made irrigation of large additional areas possible. There, also, the large ground-water resources were of great value during the recent drought in Arizona, when the Roosevelt Dam and other surface storages in the Salt River Valley went dry.

Further North there are extensive ground-water supplies in the Willamette Valley, but so are there abundant surface supplies. The irrigation season is short, but the added return per acre of irrigated lands is large. Pumping by the individual farmer for specialty crops has been found most profitable. Ground-water occurrence in the Willamette Valley is not unlike that of the Central Valley of California, but its use has only begun in comparison to the extensive irrigation by ground water in California.

Glacial Moraines and Tertiary Lava Flows

The glacial moraines extend southward from Puget Sound well toward the Columbia River. These deposits furnish an abundant water supply to the city of Tacoma and several large industries. There are, however, more uncertainties of well production in the glacial till than in the alluvial deposits of the Southwest. The efficiency of many successful wells is partially offset by a number of wells of low yield.

In Eastern Washington and Oregon, Northeastern California and the Snake River Valley of Idaho are great tertiary lava flows that provide, within and beneath their mass, vast ground-water bodies that give rise to great springs. Most notable of these are the springs emerging from the vertical walls of the Snake River gorge in the vicinity of Twin Springs, Idaho. There, with no flow in the Snake River at Milner, the river has an almost constant flow of more than 6,000 cfs., entirely from springs. The exact course of ground water and the best location for wells is more difficult and uncertain to map in these lava flow regions. There is a shortage of surface water, however, and development of ground water for domestic and stock purposes would make it possible to save much off-irrigation-season canal-flow for summer irrigation.

Throughout the West development of ground water is an important element in providing sufficient stock-watering places to permit maximum utilization of the range lands without the danger of spotted over-grazing

common in many areas with less sheep or cattle, but with insufficient watering places.

Safe Yield of Raymond Basin Area

In connection with important ground-water litigation, the California State Division of Water Resources has conducted a very detailed and intensive study of the safe yield of the Raymond Basin underlying the valley area adjacent to the foothills from Pasadena to Arcadia. This ground-water basin has a surface area of 39.5 sq.mi. and a tributary mountain area of 52.7 sq.mi. Although the surface streams from the San Gabriel mountains afford an important water supply during the winter months, except when too muddy, they practically cease to flow during the summer. A number of communities have been dependent in whole or in part upon the ground water of the Raymond Basin—Pasadena, La Canada, Altadena, South Pasadena, San Marino, Alhambra, San Gabriel, Sierra Madre, Arcadia and Monrovia. The population affected is about 200,000.

The study by the Division of Water Resources acting as referee for the Superior Court required more than two and a half years and cost more than $50,000. The studies and expenditures by parties to the action covered a much longer period at substantially greater costs. Reference is made to this investigation because of a number of interesting findings, some of which astonished engineers having years of intimate contact with the local conditions. The study was made in co-operation with a board of engineers representing the parties to the litigation and monthly meetings were held during the progress of the work. The investigation was so well and thoroughly done that the conclusions are fairly well accepted by the disputing parties and it seems likely that the expected expensive litigation may be terminated by an agreement between all parties, resulting in a stipulated decree.

Extensive hydrologic data collected by local water companies, districts and cities, by the U.S. Geological Survey, the U.S. Weather Bureau, the Los Angeles County Flood Control District and the State Division of Water Resources in its prior studies of the South Coastal Basin made it possible to determine water production records from 1913 to 1938. These data included: (1) sources of water—rainfall in the mountains and on the valley floor, runoff from surface streams as they emerge from the mountains and again as they pass the lower limit of the Raymond Basin, importation of water, deep percolation from irrigation and domestic use; and (2) losses from the Raymond Basin—surface runoff in stream courses and storm drains, exportation of water and sewage, evaporation and transpiration losses from the ground surface, involving a detailed classification of surface culture and crops, and ground-water leakage past the Raymond

Dike, a ground-water barrier largely in the alluvium caused by block-faulting. Ground-water capacities were determined from many well logs and records of water levels. Extensive soil moisture studies were made.

Owing to time lags it was found impracticable to determine the supply, draft and overdraft on the basin each year. It was found most satisfactory to select the 11-yr. period 1927–28 to 1937–38, inclusive. The first 6 yr. of this period were below normal and the last 5 yr. above normal in rainfall. The total for the 11-yr. period was slightly above normal, requiring some

TABLE 2

*Summary of Hydrologic Data for Raymond Basin**

	STAGE OF DEVELOPMENT		
	Natural	Present	Ultimate
	acre-ft. †	*acre-ft.* †	*acre-ft.* †
Surface inflow in streams	21,740	21,740	21,740
Surface outflow in streams	18,510	15,330	20,530
Total water used	0	23,850	34,440
Sewage outflow	0	5,920	13,710
Consumptive use	42,110	40,080	39,400
Deep percolation from:			
Precipitation	4,120	11,080	12,560
Irrigation	0	2,770	3,140
Distribution system losses	0	1,200	1,640
Cesspools	0	2,490	0
Streams	14,880	7,780	5,780
Total	19,000	25,320	23,120
Underflow from basin	7,270	3,480	3,480
Safe yield	15,520‡	21,840	19,640

* Total area, 25,217 acres; area of basin, 40 sq.mi.; tributary mountain area, 53 sq.mi.; average annual rainfall, 21.96 in.

† To secure values in mil.gal. multiply by 0.326.

‡ Safe yield under natural conditions based on present ground-water levels and underflow of basin.

correction to the 29-yr. period 1904–05 to 1932–33, which was agreed upon as the period giving normal rainfall and runoff.

It should be noted, however, that the present and ultimate conditions are maintained by a surface water use of 23,850 and 34,440 acre-ft., respectively, or 2,010 and 14,800 acre-ft., respectively, in excess of the safe yield of the basin. Actually much more water must be imported than shown by these figures owing to export rights to a portion of the safe yield. It is expected that parties will agree to a reduction of their pumping from 31,400 to 21,840 acre-ft. per annum.

Among the many interesting items to note in Table 2 is the relatively small change in consumptive use from the natural conditions (about one-half brush and woods cover and the other half annual grass cover) to the present urban development with an overlying population of some 120,000. Similarly in the final stage of maximum ultimate urban development there is relatively little change in consumptive use, deep percolation or safe yield. The explanation of this apparent paradox is that the loss to deep percolation arising from the construction of roofs, paving of streets, walks and drives, and the construction of storm drains and paving of channels is compensated for by the lessened area subject to evaporation and transpiration losses and the greater proportion of deep percolation from rainfall and irrigation, resulting from artificial application of water to lawn, shrub and crop areas. These results were not foreseen or easily understood, even by engineers. Only those who had made a long and intimate study of the problem were aware of the situation.

More discussion has been given to this study of the Raymond Basin than its size or even the large population and assessed values involved would seem to justify, because of the broad basic importance of the knowledge of safe yield of ground-water basins. Unless other supplies are available for importation, the overdeveloped ground-water basin frequently presents a great economic loss and a tragedy to those who have invested their life's work and savings. In some instances artificial spreading of water will greatly increase the replenishment and safe yield of such basins.

Increasing Storage by Water Spreading

The practice of spreading water to increase ground-water storage has been practiced for many years in the semi-arid West. As early as 1896 it was being practiced on the extensive Irvine Ranch in Orange County, Southern California, by spreading the water of Santiago Creek on the adjacent lands. Since that time the practice has become widely adopted by irrigation companies and districts, water companies and cities. In many cases, special conservation districts have been formed for that purpose. As this practice is primarily a western development, adopted in Arizona, California, Oregon, Texas, Utah and Washington, some description of the methods followed should be included.

There are three common methods of spreading: the basin method, the furrow or ditch method and the flooding method. A fourth method by use of pits, shafts and drilled wells is less frequently successfully practiced. Each local geologic, topographic and hydrologic situation involves study to determine the best and most economic means. It is not infrequent to find that all three methods are followed in one project, and sometimes all four.

No spreading system is satisfactory if the water to be spread carries a high percentage of silt. The clearest water is required where shafts are

used. Basins, flooding and ditch methods, in that order, have increasing ability to handle silt-laden water.

Surface storage is most valuable to spreading operations, in that it stores water during periods of streamflow in excess of the capacity to absorb water of the natural channels and spreading grounds; it stores silt and debris during floods, making possible the release of clearer water; and increases the time, and thus the quantity, of water that may percolate in natural channels and spreading grounds. Water conservation by spreading is, therefore, ideal in combination with flood-control storage. The peak flows are caught in surface storage reservoirs and then rapidly released in more clarified condition to percolate into the ground, making the surface storage available for later peak flows. Notable examples of such flood-control storage and spreading operations are the Los Angeles CountyFlood Control District and the Santa Clara County Water Conservation District.

An exceptional case of utilization of ground-water storage to supplement surface storage for a large domestic water supply system is found in the water-spreading operations of Los Angeles. The city spreads more than 100 cfs. on 47 acres of land, in the easterly portion of the San Fernando Valley, with a minimum wet-year usable ground-water storage capacity of 150,000 acre-ft. Water is brought to the spreading grounds more than 250 miles from Mono Basin and Owens Valley through the Los Angeles Aqueduct. Costs of this ground water storage, including capital investment, are said to be as low as $0.66 per acre-ft. compared to $8.93 per acre-ft. for water stored in surface storage reservoirs in San Fernando Valley. Los Angeles is able to recover this water by deep well pumps or by gravity diversion from the Los Angeles River, a perennial stream fed by the ground water of San Fernando Valley.

Not all water spreading costs are so low; in fact, the quantity of water salvaged by the spreading operations is frequently overestimated by failure to deduct the quantity of water which would have percolated under natural conditions without artificial spreading. The costs are frequently underestimated by failure to include capital costs of land or works, or both, and by charging an undue portion of joint costs to flood control benefits.

In many instances, however, overdrawn ground-water basins have been brought within their safe yields by spreading operations, or water has been made available for new lands and populations which could not have been done by surface storage only, even at greatly increased costs. In the Santa Clara Valley an additional benefit appears to have been accomplished. Not only has the ground-water level been stabilized, but the ground surface as well. In the twenty years prior to 1935, the ground surface at San Jose had fallen more than 5 ft. In the seven years since

that date, spreading operations, plus favorable wet years, have prevented further recession in the ground surface and ground-water levels have risen substantially.

Ground Water and City Development

Ground water has played an important part in the development of most of the major cities of the Pacific Coast—in Spokane and Tacoma, from the great glacial moraines of Washington; and in all of the cities around San Francisco Bay from alluvial deposits. At various times in the life of San Francisco up to the time that the Hetch Hetchy supply was brought in from the Sierras, that city had to fall back upon ground-water supplies during critically dry years. Similarly, Oakland, Berkeley and the other East Bay cities had to supplement their inadequate surface water supplies with ground water up to the completion of their Mokelumne supply from the high Sierras.

Los Angeles, Pasadena, Long Beach and all the other cities in that metropolitan area of 3,000,000 population were originally almost entirely dependent upon ground water. Most of them still are. By growth in population and assessed value, and with overdrawn ground water supplies and critically lowered water planes as a springboard, Los Angeles, in 1902, went to the Owens River and completed its 250-mile aqueduct in 1913; and in 1941, with twelve other cities, completed the Colorado River Aqueduct to bring water from the Colorado River at a cost of over $200,000,000. These great imported supplies do not replace, but rather supplement the local ground water supplies that made those imported supplies both necessary and possible of accomplishment. As Bill Mulholland said in 1902 when Los Angeles had a population of 100,000 and was attempting to finance a supply adequate for a population of 1,250,000, "If you don't vote the bonds you won't need the water," a homely prediction that Los Angeles would not grow unless it got more water.

The interior cities of Ogden, Salt Lake and Phoenix have been dependent in part upon ground-water supplies. The long-time departures from normal rainfall and runoff have a way of depleting surface storage and making more impressive the less spectacular ground-water supplies which more often have large hold-over capacity.

It would be futile, however, to attempt to enumerate the contributions to the economic life and security of the West made possible by ground-water supplies. Suffice it to say that they are of great help in making water available in the dry summers and long dry cycles of years.

Chemical Character of Public Water Supplies in Southeastern Florida

By S. K. Love and H. A. Swenson

THE analyses given in Table 1 show the chemical character of the 25 public water supplies in six counties in southeastern Florida. These analyses were made by the U.S. Geological Survey in connection with an intensive investigation of water resources in southeastern Florida in cooperation with Dade County and the cities of Miami, Miami Beach, and Coral Gables.

A total population of over 300,000 is served by the 25 supply systems. Ground water is furnished by 18 places to a population of about 275,000 and surface water is furnished by 7 places to a population of about 50,000.

Miami, the largest city in the area, obtains its supply from wells and furnishes water to Miami Beach, Coral Gables and several smaller communities. Other cities and towns using ground water are Boca Raton, Boynton Beach, Dania, Deerfield Beach, Delray Beach, Fort Lauderdale, Hollywood, Homestead, La Belle, Lake Park, Lake Worth, Lantana, North Miami, North Miami Beach, Opa Locka, Pompano and Riviera.

West Palm Beach is the largest city using surface water. Palm Beach is also supplied by this system. Other towns supplied with surface water are Belle Glade, Canal Point, Clewiston, Moore Haven, Okeechobee and Pahokee. These six towns are located on or near Lake Okeechobee and are normally supplied with lake water.

The hardness of the finished water from the 25 supplies is indicated on Fig. 1, which shows that 22 places furnish water with a hardness of less than 201 ppm. and that 8 places, representing about 70 per cent of the population supplied, furnish water with a hardness of less than 121 ppm.

Economic development in southeastern Florida centers largely around agriculture and the entertainment of winter visitors. Much the largest

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Condensed from a paper presented in April 1942 at the Memphis meeting of the American Chemical Society, by S. K. Love, Assoc. Chemist, and H. A. Swenson, Jr. Chemist, U.S. Geological Survey, U.S. Dept. of the Interior, Washington, D.C. Published by permission of the Director, U.S. Geological Survey.

use of water from the public supplies is for domestic purposes. Agricultural use of water from public supplies is very small. Irrigation is practiced during dry periods, but water for this purpose is usually obtained from shallow wells or drainage canals.

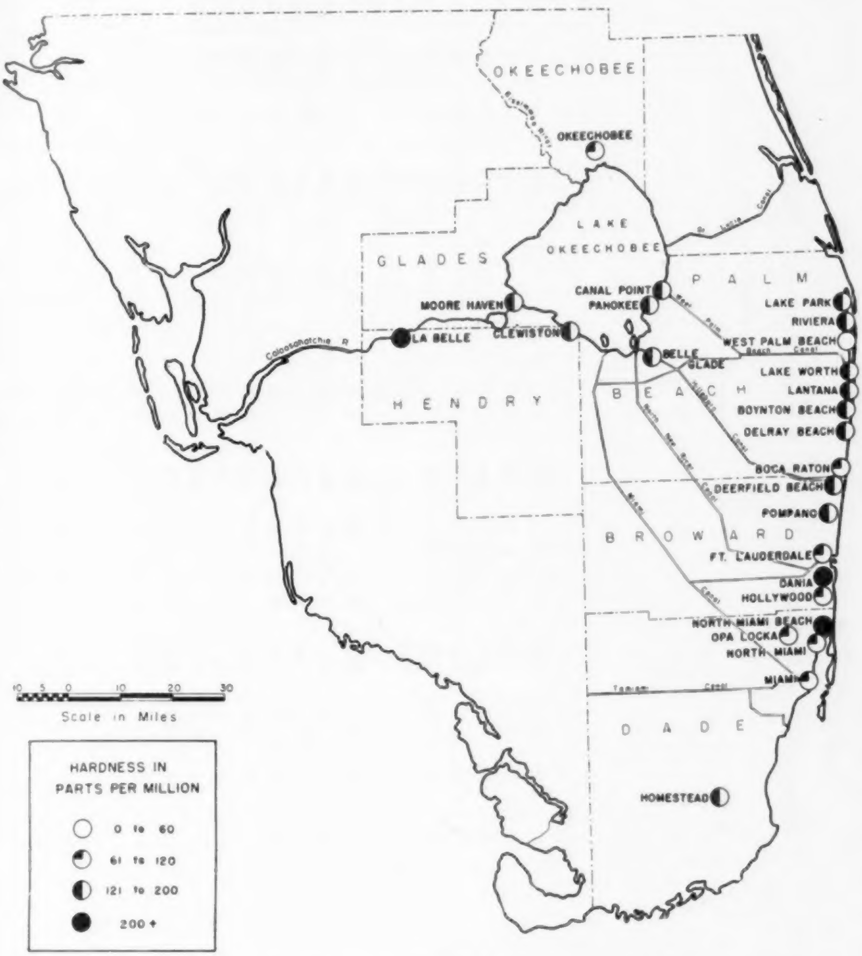


FIG. 1. Hardness of Public Water Supplies in Southeastern Florida, 1941

There is practically no heavy industry in the southeastern part of the state. Most of the industrial plants in the coastal cities are connected directly or indirectly with the building trades or public services and a large part of the water used by them is obtained from privately owned wells.

TABLE 1

Analyses of Public Water Supplies in Southeastern Florida, 1941

MUNICIPALITY	TYPE OF WATER*	COLOR	pH	PARTS PER MILLION													
				Total dissolved solids	SiO_2	Fe	Ca	Mg	Na	Na + K	K	HCO_3	SO_4	Cl	F	NO_3	Total hardness as $CaCO_3$
Broward County																	
Dania	D	90	7.8	365	7.6	0.12	104	3.5		16		302	25	25	0.3	0.7	274
Deerfield Beach	D	25	7.4	164	8.0	0.65	51	3.1		5.3		153	7.6	13	0.2	0.0	140
Ft. Lauderdale	R	110	7.3	294	11	1.9	88	3.3	11		1.4	266	2.4	18	0.1	2.1	233
Ft. Lauderdale	F	35	7.7	115	6.8	0.05	21	2.9	10		1.3	44	16	18	0.2	3.2	64
Hollywood	R	40	7.1	333	3.2	0.24	103	2.6		10		301	19	17	0.2	0.1	268
Hollywood	F	40	7.7	437	4.0	0.08	40	1.0		91		307	20	20	0.2	0.1	104
Pompano	D	20	7.2	165	4.8	0.16	47	2.3		8.0		136	11	15	0.4	0.1	127
Dade County																	
Homestead	D	5	—	212	2.8	0.02	63	6.5		7.2		218	8.3	10	0.2	0.3	184
Miami	R	85	6.8	370	7.4	1.3	94	9.6	22		2.2	266	34	38	0.1	1.5	274
Miami	F	20	8.5	204	8.5	0.01	27	6.1	25		2.0	40†	38	48	0.2	0.1	92
North Miami	R	60	7.5	363	5.2	0.32	99	3.8		8.2		255	47	16	0.2	0.1	263
North Miami	F	20	8.4	178	7.6	0.12	29	2.4		9.5		38‡	47	16	0.3	0.5	82
North Miami Beach	R	40	7.1	1279	7.6	1.5	176	3.3		132		285	25	340	0.2	0.0	453
North Miami Beach	F	20	8.0	939	10	0.08	80	2.4		114		17§	26	295	0.3	0.0	210
Opa Locka	R	70	7.2	244	6.0	0.68	72	4.5		5.1		216	16	11	0.3	0.1	198
Opa Locka	F	40	7.8	138	6.0	0.08	30	4.2		—		70	20	11	0.3	0.5	92
Glades County																	
Moore Haven‖	R	80	—	487	8.4	2.2	104	13		25		312	44	43	0.3	5.0	313
Moore Haven‖	F	30	—	534	7.2	0.15	88	12		70		282	117	45	0.0	5.0	269

Hendry County																	
Clewiston	D	5	7.0	248	3.5	0.03	41	9.7	24		2.0	76	75	36	0.1	2.1	142
La Belle	D	5	—	1595	26	0.16	65	53		349		118	325	500	2.4	—	380
Okeechobee County																	
Okeechobee	D	8	6.8	114	1.3	0.06	19	3.1	9.5		1.6	22	40	17	0.1	0.2	61
Palm Beach County																	
Belle Glade	D	40	—	692	13	0.09	91	31		63		218	185	83	0.1	5.0	355
Boca Raton	R	10	7.2	195	9.6	0.06	59	3.1		2.6		168	2.0	18	0.3	0.7	160
Boca Raton	F	10	7.4	97	5.2	0.02	22	1.6		8.3		56	9.1	17	0.3	0.2	61
Boynton Beach	D	30	7.3	227	5.2	0.04	66	2.8		7.5		178	16	21	0.3	0.5	176
Canal Point	D	25	—	311	3.8	0.13	46	12		29		127	54	47	0.1	1.0	164
Delray Beach	D	35	7.6	234	3.2	0.20	70	2.8		8.5		205	4.9	22	0.2	0.8	186
Lake Park¶	D	10	7.5	200	6.4	0.04	58	2.3		8.1		162	9.5	17	0.2	6.5	154
Lake Worth	D	40	—	287	4.8	0.72	74	3.1		19		220	20	25	0.1	4.0	197
Lantana	D	10	7.2	182	6.8	0.06	54	3.3		3.6		152	3.0	20	0.3	0.2	148
Pahokee	D	35	—	371	7.6	0.06	56	16		29		160	67	47	0.3	3.0	206
Riviera	D	15	7.8	194	6.8	0.17	48	1.9		17		153	2.8	25	0.3	1.0	128
West Palm Beach	R	55	6.4	49	1.0	0.04	7.1	0.9	4.8		0.9	16	1.6	9.5	0.1	1.0	21
West Palm Beach	F	5	9.0	87	3.6	0.02	17	1.1	5.2		1.1	26**	23	11	0.1	0.0	47
Lake Okeechobee††		47	—	236	8.9	0.05	39	9.7	25		1.7	134	25	37	0.2	0.7	138

* *Key:* D—delivered; R—raw; F—finished.
† Includes equivalent of 3.9 parts of CO_3.
‡ Includes equivalent of 9.8 parts of CO_3.
§ Includes equivalent of 4.9 parts of CO_3.
‖ Well water.
¶ Formerly Kelsey City.
** Includes equivalent of 6.9 parts of CO_3.
†† At St. Lucie Canal.

Several Army and Navy air fields and training bases have been established along the lower east coast of Florida. Existing public supplies furnish water to some of them while others have installed their own supplies. Water from public supply systems is also furnished to shipping at Miami, Port Everglades and the Port of Palm Beach.

Although the future industrial demands for large quantities of water may be a factor in the development of public supply systems in southeastern Florida, the present requirements for adequate supplies of water of acceptable character, particularly in the coastal cities, are determined largely by the influx of winter visitors.

Errata

Studies on Maximum Momentary Demand, by A. P. KURANZ, in the October 1942 issue:

1. Page 1539, line 5 under the heading "San Francisco": *for* he used 15 gpm. *read* he used 7 gpm.
2. Page 1542, Table 3, Column 4, NO. OF FAUCETS, line 5: *for* 38 *read* 48.

Capacity Tests of Ground-Water Sources at Laramie, Wyoming

By R. D. Goodrich

THE city of Laramie has been most fortunate in deriving its water supply from springs at an elevation of a hundred feet or more above the business district, with the nearest ones only two miles distant. These springs are held jointly by the city and the Union Pacific Railroad and are located just at the foot of the Laramie Range, east of the city. In past years, as population increased and the demand for water grew, additional rights were secured in other springs farther south, also at the foot of the mountain range.

The quality of this supply of spring water is excellent for domestic use, being clear, sparkling and cold the year round. It does not require treatment of any kind, although it is too hard for certain industrial uses without softening. It is therefore most natural that the public demand that any additions to the water supply from other sources should be of similar character, as was demonstrated about four years ago when the voters rejected a bond issue, designed to secure an adequate supply of treated water from the Laramie River. Such public refusals to changes in source are most common and persist despite engineering and geologic reports as to the very limited quantity obtainable from available sources of the same type.

Following public rejection of the plan to use surface supply, the consideration of the question of additional water was referred to a representative committee of citizens which devoted several months of study to the problem. Its recommendations included that of securing a large additional supply from the river, but the committee recognized the fact that it might be necessary first to try some form of temporary development of additional ground water, to determine those possibilities and to satisfy public demand on that score.

A paper presented on September 17, 1942, at the Rocky Mountain Section Meeting, Denver, Colo., by R. D. Goodrich, Dean, College of Engineering, Univ. of Wyoming, Laramie, Wyo.

During the past year, therefore, three wells have been drilled east of Laramie and near the City Springs. The author was employed to conduct tests of these wells and to report his findings. His report to the city, with but few alterations, constitutes the following discussion.

Test Procedure

Prior to making these tests, a preliminary test of well No. 1 was made during the last week of February 1942. Following this, the "Parshall Flume," which is used to measure the flow of the springs, was moved from its temporary location to a permanent setting in the pipeline leading to the west reservoir. A recording gage was also installed so that a continuous record of flow from the springs could be obtained and so that the effect, if any, of pumping could be shown graphically. The discharge from the wells was measured by an orifice meter with a $5\frac{1}{2}$-in. orifice in the 8-in. delivery pipe from the wells.

Wells of the type involved are tested by pumping at a constant rate for a sufficient length of time so that the sum of the flows from the two sources, well and springs, becomes stabilized. When the total recovery of ground water is constant at the observed rates from the well and springs for a number of days, the rate of inflow to the ground-water area tributary to the well and springs is equal to the rate of outflow, or to the rate of recovery of ground water. If the rate of flow from the springs continues to decrease, although the rate of pumping remains constant, more water is being taken out than is flowing into the recharge area. On the other hand, if the flow from the springs remains constant while the rate of pumping is gradually increased, there is greater inflow into the area tributary to the springs than is being recovered, or there is no connection between the sources of the springs and wells.

In the tests of both Laramie wells, after about a week of continuous pumping, the total outflow from the well and the springs remained practically constant for the record week of pumping. Therefore, the input and output were equal, and the total available recovery from each well was as reported in Item 5 of Table 1. These results were checked by a different method of computation which showed a discrepancy of less than 5 per cent, indicating the reliability of the results of the tests.

Test of Well No. 1

Well No. 1 was tested in April 1942, by a practically continuous operation of the pump for twelve days. For the last week of pumping, the total recovery of ground water from well and springs was at the average rate of 1,740,000 gpd., of which 810,000 gpd. was from the well and 930,000 gpd., from the springs. This represented an increase of only 110,000 gpd., or

6.75 per cent, above the flow from the springs alone. To secure this small increase, 43 per cent of the total flow was pumped, indicating that the practice was uneconomical. It was, therefore, reported that the use of this well to add to the city supply was not justified.

The close connection between this well and the springs is evidently due to fractures or fissures in the water-bearing formation, which have been enlarged into definite channels by the gradual dissolution of calcareous material (lime and limestone) through centuries of flow from the springs. The hardness of the spring water is evidence that this process is still going on. Before beginning the test of the well, the elevation of the water surface in both wells was 7,267.6 ft. above mean sea-level. This is about 4 ft. higher than the main spring, and about 6 ft. higher than the water level of the springs nearest well No. 1. The main spring is about equally distant from the two wells tested.

With a lowering of the water level by pumping, i.e., with a drawdown of 5.4 ft., the elevation of the water surface in the well was reduced to 7,262.2, which was only 0.5 ft. above that of the nearest spring. It would have been very easy to have pumped the well at a higher rate and to have lowered the ground water below that at the springs. In fact, the flow of most, if not all, of the springs could have been stopped entirely, with consequent danger of plugging some or all of the springs. This is practically what has happened at Pope Springs, where through drilling and pumping of wells, the springs have been entirely dried up, so that all ground water must now be recovered from the area by pumping.

Following the two weeks of pumping well No. 1, a rise of water level in all wells was observed and the recovery of the spring flow to its original value was recorded. The time required was only one week—much less than was to be expected. Since the flow of the springs continued to increase slowly for several days more while the static head in the wells also increased above the original head, it is evident that the effect of the two weeks of stormy weather which followed the pumping test, exerted an almost immediate effect on ground water conditions. It was previously thought that there was a lag of weeks or months between the occurrence of precipitation and its effect upon spring flow.

Test of Well No. 2

Well No. 2 was tested in May by continuous pumping for sixteen days. Again the second week of pumping was at practically uniform rate, with constant flow from the springs. For the week before this test, the total flow of the City Springs averaged 1,716,000 gpd. During the final week of pumping, the flow of the springs had been reduced just a third, while the total recovery of ground water from the area was 1,907,000 gpd. The

increase above the previous spring flow was 191,000 gpd., or 11 per cent. The recharge rate of about 1,900,000 gpd. for the available ground water supply tributary to this well and the springs, is 167,000 gpd. more than that for well No. 1. This is to be expected, since well No. 2 is more than twice as deep and therefore should tap a greater depth of water-bearing formations (aquifers); and the additional water is evidently from the lower aquifers. The 11-per cent increase in yield, however, is again far too small to justify the cost of pumping 40 per cent of the total ground water recovered.

On the whole, this deeper well is the better one, since it caused a little less reduction in the flow of the springs, although its drawdown was twice as great as for well No. 1, while the specific yield was only half as great. The drawdown of 10 ft. required to get as high a production from well No. 2 as from No. 1 must have been the result of denser or less fractured formations at this locality. Incidentally, the elevation of the water surface in the well during test was 5–6 ft. below the level of the springs.

Discussion of Test Results

It may be thought that by pumping both wells at once, a greater increase would be secured in the additional ground-water recovery. While this is undoubtedly true, the quantity recoverable would be only 65–85 per cent of the sum of the quantities produced from the two wells when pumped individually. In this case, it is estimated that the yield from the two wells, when pumped at the same time, would be 84 per cent of the sum of the quantities when pumped separately. Tests of the wells, however, prove that the greater the pumpage, the less the flow from the springs. The net result, therefore, is a practical limit of about 15 per cent net increase to be gained by pumping at least 50 per cent of the total ground water recovered in the area.

As previously stated, if greater ground-water recovery is accomplished by heavier pumping, it will be at a rate greater than the recharge rate of the area, and this would result in permanent decrease in this water supply. Such procedure would be justified only during development of a large independent source while additional demands, as for war emergency work, required an immediate temporary increase in supply. This procedure would probably permanently dry up the city springs, as has been done elsewhere.

A laboratory test was made of the percolation rate for a sample of the sandstone or siltstone obtained by the Union Pacific geologist. This sample is typical of 64 per cent of the formation encountered in drilling well No. 2 and constitutes 87.5 per cent of the material in the lower 350 ft. of the well. For this lower section, it was determined that, in its natural

unfractured condition, this rock has a percolation rate of 0.175 cu.ft. per yr. or less, under a hydraulic gradient of unity. The amount of voids in the rock was found to be 22.1 per cent of the total value.

The fractured condition of the formation surrounding the wells gives average rates of percolation several times as great as the figures shown. The probable subsurface condition to be found in the central portion of the

TABLE 1

Results of Well Tests

ITEM	WELL NO. 1	WELL NO. 2
1. Avg. flow of springs for 1 week before tests, *gpd*...	1,630,000	1,716,000
2. Avg. flow of springs last week of test, *gpd*.....	930,000	1,151,000
3. Decreased flow from springs (No. 1, 43%; No. 2, 33%), *gpd*....	700,000	565,000
4. Avg. quantity pumped from well in last week of test (No. 1, 46.5%, No. 2, 39.5%), *gpd*.......	810,000	756,000
5. Avg. total recovery of ground water from both springs and well, *gpd*....	1,740,000	1,907,000
6. Increase above avg. flow of springs alone (No. 1, 6.75%; No. 2, 11.1%), *gpd*....	110,000	191,000
7. Specific yield of well, *gpd. per ft. drawdown*....	150,000	75,000
8. Avg. drawdown at well in last week, *ft*........	5.4	10.1
9. Time between starting and stopping of pump and effect on spring flow as recorded at measuring flume, *min*....	9	20
10. Lowering of static water level in other well than that tested, *ft*....	2.2	2.15
11. Lowering of static water level in well No. 3 during pumping, *ft*....	1.5	0.08
12. Depth of well tested, *ft*....	238	565
13. Specific yield of deep well 3 mi. east of Soldier and Pope Springs,* *gpd. per ft. drawdown*....	—	650

* Records of City Engineer's office (June 9, 1942) show that the discharge at Soldier Springs decreased from 1,292,000 to 1,144,000 gpd. This is reduction of 11.4% since May 25, when test of well No. 2 completed and additional pumping at Pope Springs started.

Laramie River basin would give about the same percolation rates as found in the laboratory for this material.

The specific yield for a deep artesian well in the central portion of the Laramie basin, south of the city, was found to be 650 gpd. per ft. of drawdown, with 200 ft. of drawdown and a total depth of approximately 1,500 ft. The average yield of the well is 130,000 gpd. If a series of these wells were spaced at half-mile intervals across the central portion of this artesian

basin, their yield, when pumped simultaneously, would not exceed 85 per cent of this value, or 110,000 gpd. It would therefore require 15 such deep wells in the river basin to equal present flow from the City Springs, and not less than 25 wells to equal the present total city supply. If these wells were not to draw on the limited ground-water supply of the various spring areas in the city water system, it would be necessary to place them several miles north or south of the city. At a minimum cost of $15,000 per well, the cost of 25 wells would be $375,000. To this would be added the cost of land and right of way, pumping plant, connecting pipelines between wells, the pipeline to deliver the water to the city and electric power distribution to well pumps and to the main pumping plant. If any of this development caused a loss in flow from the springs, as is more than likely, the number of deep wells would have to be increased accordingly.

Careful consideration of all the records and tests available, then, led to the conclusion that further consideration of wells, especially of wells in the area tributary to any of the springs connected with the city system, would be uneconomical and unjustified. Furthermore, it was reported that the underground supply had not been demonstrated to be sufficient for anything but temporary or emergency uses, and that the cost of an adequate system of wells in the Laramie basin would be prohibitive in view of the fact that other more dependable sources are available.

Steel Siphon Rehabilitation on the Los Angeles Aqueduct

By W. W. Hurlbut, Burton S. Grant and H. Arthur Price

INCLUDED in the Los Angeles Owens River Aqueduct (Fig. 1), which was constructed between 1907 and 1913, are 22 inverted siphons, 12 of which were constructed of steel, 8, of concrete, and 2, of a combination of steel and concrete. Altogether, these siphons constitute approximately 12 mi. of the 240 mi. total length of the Aqueduct system.

Among the fourteen steel siphons, heads range from 67 to 850 ft. A minimum plate thickness of $\frac{1}{4}$ in. was used, a maximum of $1\frac{1}{8}$ in. being required in the Jawbone Siphon on which there is a head of 850 ft. Pipe diameters vary according to plate thicknesses and range from $7\frac{1}{2}$ to 11 ft.

All joints were riveted because arc welding was not in common usage at the time of construction and the type of joint employed was based on plate thickness. Butt straps were employed for joints on all pipe constructed of plate over $\frac{1}{2}$ in. in thickness: circumferential joints were double-riveted and longitudinal joints were triple-riveted. All such pipe was shop-riveted into two ring sections of 12-ft. lengths, except the thicker plates across the bottom of the siphons, which were shop-riveted in longer sections. Lap joints were used on all pipe fabricated of plate $\frac{1}{2}$ in. or less in thickness; circumferential joints were single-riveted and longitudinal joints were double- and triple-riveted. All such plate was sheared for outside calking and all rivets were driven in the field.

Inspection of the specifications for steel plate and rivets in 1910 indicates that greater progress was made in the manufacture of steel than in protective coatings. Specifications for steel plate and rivets used on the aqueduct siphons in 1910 were based on the Hartford Steam Boiler Code.

Some of the elements considered in these specifications are shown in Table 1. Other factors covered were as follows:

"The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

A paper presented on June 24, 1942, at the Chicago Conference by W. W. Hurlbut, Asst. Chief Engr. & Gen. Mgr., Burton S. Grant, Engr.-in-Charge, Los Angeles Owens River Aqueduct, and H. Arthur Price, Asst. Specification Engr., all of the Bureau of Water Works and Supply, Los Angeles.

"Chemical determinations of the percentages of carbon, phosphorous, sulfur and manganese shall be made by the contractor from a test ingot taken at the time of the pouring of each melt of steel and a correct copy of such analysis shall be furnished to the engineer. Check analyses shall be

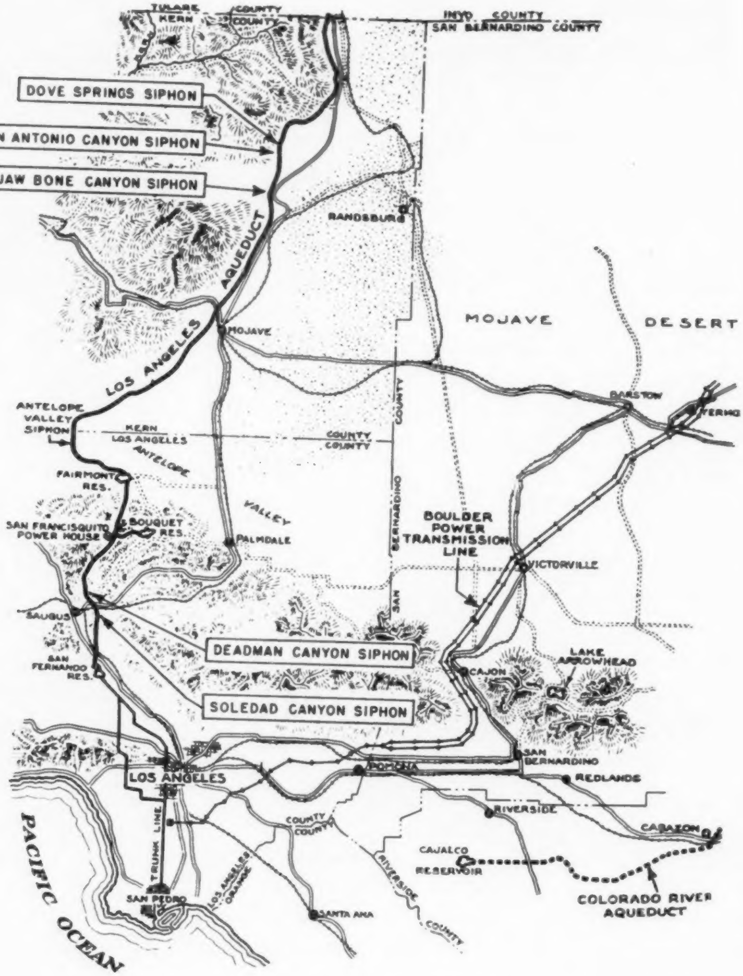


FIG. 1. Los Angeles Owens River Aqueduct; showing reconstructed siphons

made from finished material, if called for by the engineer, in which case an excess of 25 per cent above the required limits will be allowed."

Protective coatings for steel pipes, on the other hand, had received comparatively little attention as shown by the difference between specifica-

tions in 1910 and at present. Following are the specifications for "Water Gas Tar," which were used in coating both the interior and exterior of these siphons:

"Water Gas Tar shall be reasonably free from water or other impurities and not heated to the point of thickening."

Not until 1927 was any particular attention given to the use of protective coatings other than that purchased under the above specifications. In 1927, however, engineers of the Bureau of Water Works and Supply of Los Angeles began to investigate the properties of coal-tar pitches and made extensive research into the ideal properties of a protective enamel. These studies later served as an aid in the establishment of the A.W.W.A. standard specifications on coal-tar protective coatings.*

TABLE 1

Steel Plate Specifications, January 1, 1910, for the Los Angeles Owens River Aqueduct Siphons

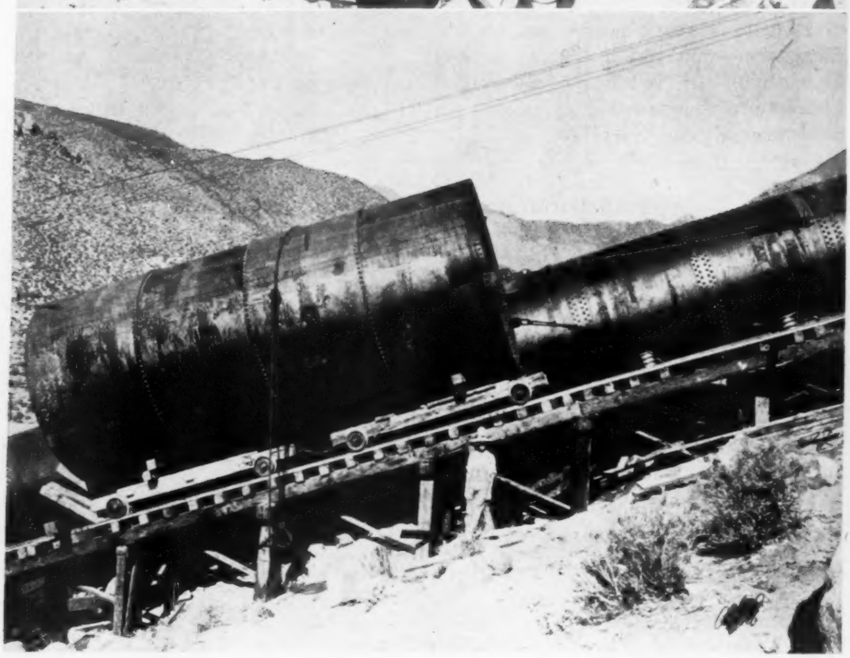
ELEMENTS CONSIDERED	PLATE STEEL	RIVET STEEL
Phosphorus, max.—basic, %	0.04	0.04
Phosphorus, max.—acid, %	0.06	0.04
Sulfur, max., %	0.05	0.04
Ult. tensile strength desired, *psi*	60,000	50,000
Elongation—min. in 8 in., %	25	30
Elongation—min. in 2 in., %	22	—
Character of fracture	Silky	Silky
Cold bend without fracture	180° flat	180° flat

Transportation and Handling Problems

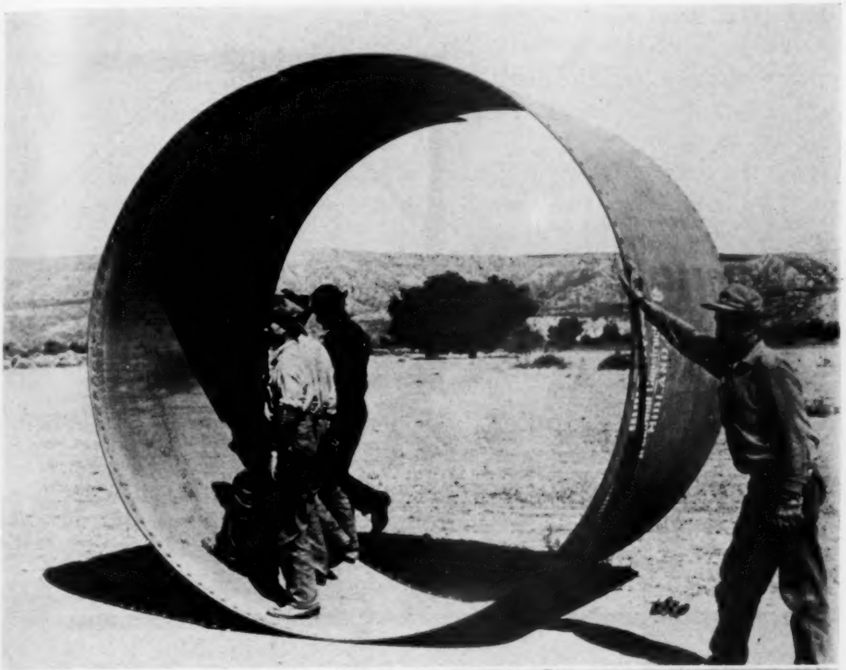
Railroads and mules were the principal modes of transportation when these siphons were constructed. A railroad was built in the vicinity of the Los Angeles Aqueduct throughout its entire length on the strength of the tonnage of materials which had to be transported for its construction. There were still distances, in excess of 10 mi. in some cases, over which these materials had to be transported by mule teams. Special pieces of equipment were constructed to carry the large loads over sandy terrain and up precipitous mountains.

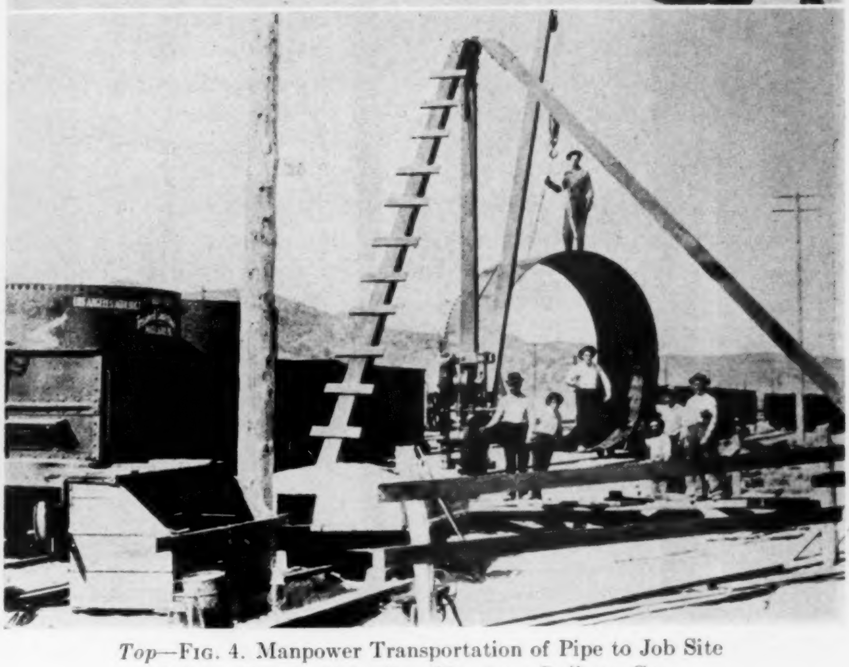
The heavier sections of the Jawbone Siphons were hauled on specially built wagons with steel wheels having 24-in. tires. The sections weighed 26 tons, were approximately 36 ft. in length and required 52 mule teams to

* Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over—7A. 5-1940 and Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes of 4½ Inches Outside Diameter up to but Not Including 30 Inches—7A. 6-1940.



Top—Fig. 2. 52-Mule Team Transporting Pipe for the Jawbone Siphons
Bottom—Fig. 3. Pipe Transportation by Tramway in Canyons for the Jawbone Siphons





Top—FIG. 4. Manpower Transportation of Pipe to Job Site
Bottom—FIG. 5. Unloading Pipe from Railway Car

Top—Fig. 6. Gantry Frame for Lining and Placing Pipe for Riveting
Bottom—Fig. 7. Pitting and Removal of Metal on Sample of Siphon

transport them from the railroad (Fig. 2). From the bottom of the canyon these sections were carried up to the proper place in the siphon by tramways (Fig. 3). Where the terrain surrounding the location of the siphon would permit, ordinary manpower was employed to transport the sections of pipe to the job site (Fig. 4).

On the thin plate, which was entirely riveted in the field, there was necessarily a great deal of handling of the pipe, as it had to be unloaded from the cars at the sidings (Fig. 5). After being transported to the location of the siphon, more rigging was necessary to line and place the pipe properly for riveting (Fig. 6).

Deterioration of Siphons

Numerous factors naturally contribute to the deterioration of these steel siphons. Effectiveness of original protective coating, quality of steel, type of water, bed-load of abrasives, fatigue from repetitive flexing caused by breathing and expansion and contraction stresses, caused by draining the siphons, have all created variations in the degree of deterioration among the fourteen siphons (Fig. 7). Five of the siphons were selected on the basis of careful detailed inspection and records of frequency of repair as requiring replacement of the thin portions. Pitting made necessary a large number of repairs to stop leaks. Although tests made on representative samples of the removed portions indicated that only a small percentage of the steel was gone, many pits had extended the full thickness of the thinner plates and required immediate patching. As the same water was carried by all siphons, the pronounced variation in corrosion between the various sections of pipe suggested variations in the original steel and protective coating quality.

Fatigue from repetitive flexing of the $\frac{1}{4}$- and $\frac{5}{16}$-in. plate due to the breathing action of the siphons causes accelerated wear over the supports, often resulting in cracks requiring immediate attention. This is particularly the case where support reaction caused a buckling of the pipe when it was filled originally or during filling and draining operations subsequently (Fig. 8). Buckling from expansion stresses also created weak points at which fatigue from breathing caused breaks, shortening the life of these pipes. Had stiffeners or shorter spans between supports been adopted originally, the breathing effects on the light plate would have been minimized greatly; or if the breathing effect could have been eliminated, the breakage due to buckling would have been eliminated largely.

Rivet wear from abrasives carried by the water had not as yet required major repairs (Fig. 9), but in time would have caused a weakness of proportions which might have resulted in complete destruction of the thin sections. Fortunately, the effect of pitting and fatigue was gradual instead

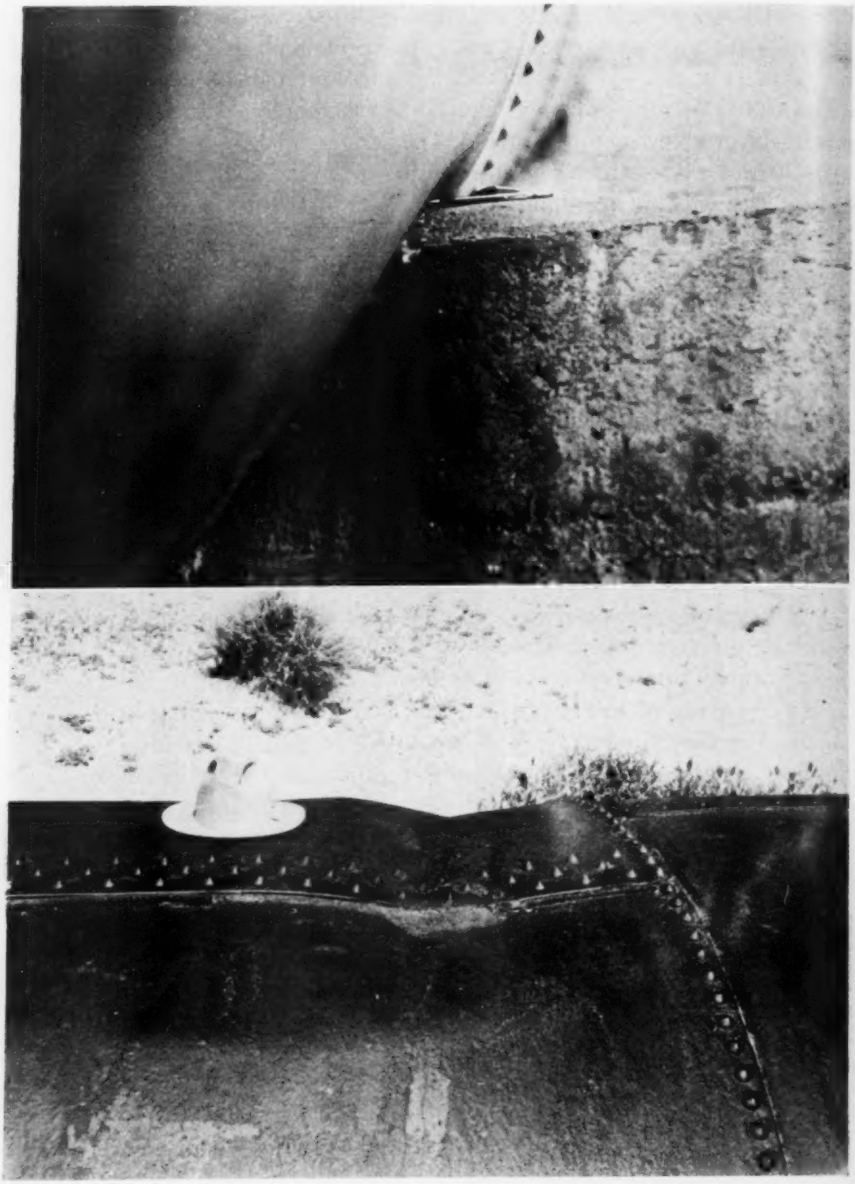
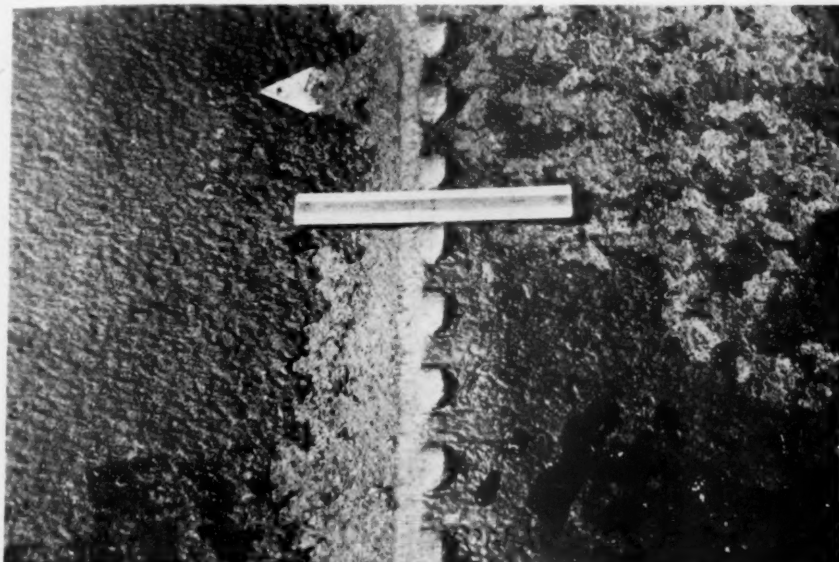


FIG. 8. Buckling of Pipe: *Top*, Over Pier; *Bottom*, At Top of Pipe



Top—Fig. 9. Inside Bottom Rivet Wear on Siphons
Bottom—Fig. 10. Patch at Top of Pipe

Top—FIG. 11. Collapsed Section of Pipe on the Soledad Siphon
Bottom—FIG. 12. Relocation of the Soledad Siphon

of sudden as might have been the case of rivet wear. The result of the latter might have been the failure of a complete joint before any symptoms were evident.

The thin portions of these siphons are at the top, on each side of the canyon crossed, usually on steep slopes where small quantities of leak water would cause considerable cutting. This cutting tends to undermine the piers supporting the structure below, so that extreme vigilance was necessary in checking their condition. The slightest sweat appearing at any point on the pipes was investigated thoroughly and if a weakness was suggested by a pit, repetitive movement at a buckle or apparent rivet weakness, a patch was applied immediately (Fig. 10). In some cases

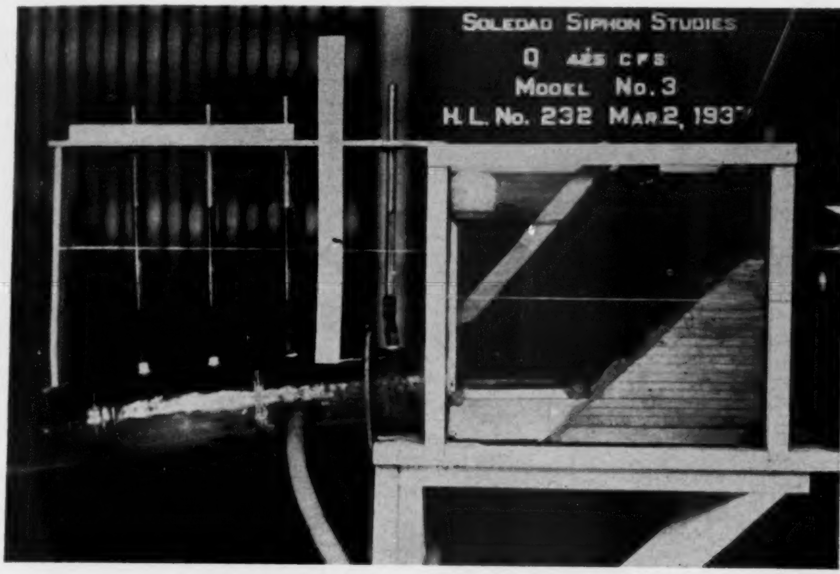


FIG. 13. Scale Model of Concrete Surge Box

large patches over small ones applied some years previously were necessary to prevent breakage.

Without stiffeners, the $\frac{1}{4}$-in. steel on such large diameter pipes did not permit of a rigid structure, supported by the method employed. Draining the pipes for inspection and repair was most damaging. Impending collapse and squirming due to expansion, together with buckling over the supports, became more pronounced with the age of the structures and a terrific toll was taken on each occasion of draining. After each draining, several weeks were required to do the calking necessary to stop rivet and joint leaks. The lack of rigidity prohibited effective coating protection with coal-tar enamels or cement.

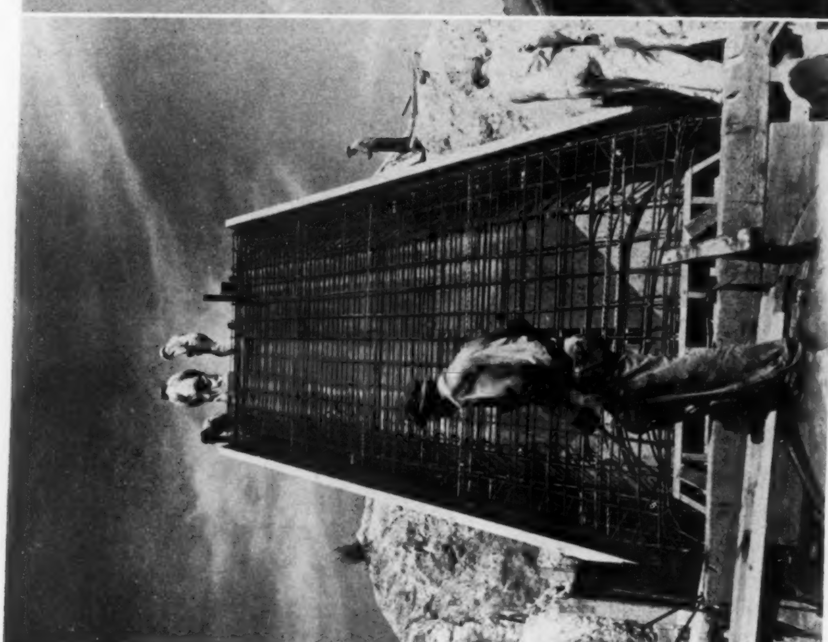


FIG. 14. Concrete Surge Box at the Head of the Soledad Siphon

FIG. 15. Removal of Old Steel With Modern Cutting Torch

A considerable portion of the section of the Soledad Siphon which was replaced finally gave up entirely and collapsed upon the final draining for the replacement job (Fig. 11). Although such collapse is not new in the history of these siphons, it does not add strength and life to such structures.

Replacement Considerations

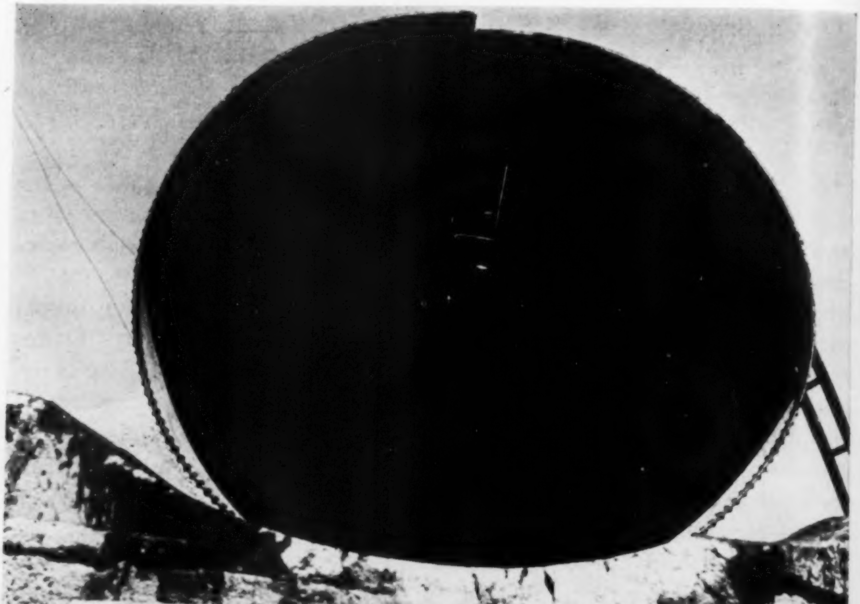
As early as 1933 consideration was given to the eventual necessity of replacing these siphons, particularly the thinner plates. Although corrosion had removed a negligible portion of the original plate, other factors which contribute to the deterioration of the pipes were not given proper consideration originally and consequently a comparatively short life was experienced by the lighter sections of the structures. In 1938 it was decided that the lightest portions of the siphons which were in questionable condition would be replaced with new welded pipe rather than to jeopardize the safety of the entire structures by attempting to get extended use from the weakened portions.

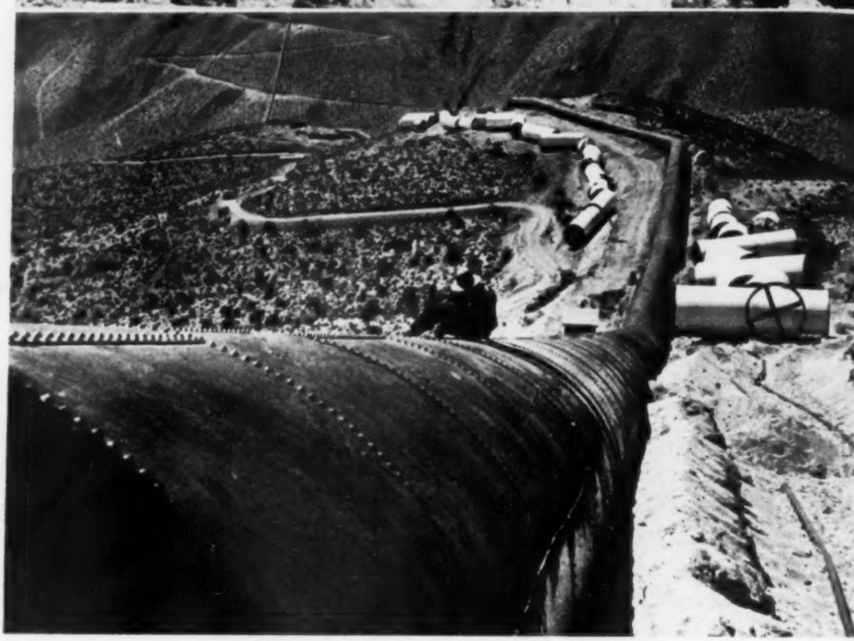
Investigations were initiated several years prior to the actual replacement to ascertain the possible effect of flexing of the pipe on coal-tar enamels and to determine the appropriate flow coefficient to be adopted for the welded enameled pipe. The investigations demonstrated that the increased rigidity which would obtain through use of pipe of $\frac{3}{8}$-in. shell thickness would prevent cracking of coal-tar enamels and would materially reduce the deterioration due to flexing. Actual practical demonstration of this fact was present in the portions of the siphons where plate $\frac{3}{8}$ in. and greater in thickness was used.

An assumed value of n of 0.018 was adopted for the original design of these siphons, whereas flow tests made as a part of the investigations preliminary to replacement gave an average value of n of 0.015 over the 14 siphons. In view of a lack of background of engineering investigation of coefficients of large diameter welded enameled pipes, it was decided to adopt a conservative value of n for the new designs based on the values found on the existing siphons. The value adopted—0.014—permitted an effective saving in pipe diameter over the original siphons. In place of pipe 11 ft. in diameter, new 10-ft. pipe was used; and in other cases 9-ft. pipe was replaced with pipe $8\frac{1}{2}$ ft. in diameter.

With the saving of steel effected by reduction of the diameter and added life resulting through use of the heavier plate, it was found economically feasible to replace the old portions of the siphons having shell thicknesses of $\frac{1}{4}$ and $\frac{5}{16}$-in. with $\frac{3}{8}$-in. plate. This decision satisfied the question of rigidity required for the satisfactory application of coal-tar enamels.

Wherever possible, angles were eliminated and the siphons shortened, to save steel, by cutting through hills, by use of higher piers, and in one case, by complete relocation on a new right of way (Fig. 12).





Top—Fig. 16. Silhouetted Cuts at Top of Siphon
Bottom—Fig. 17. Demolition Side Cuts on Siphon

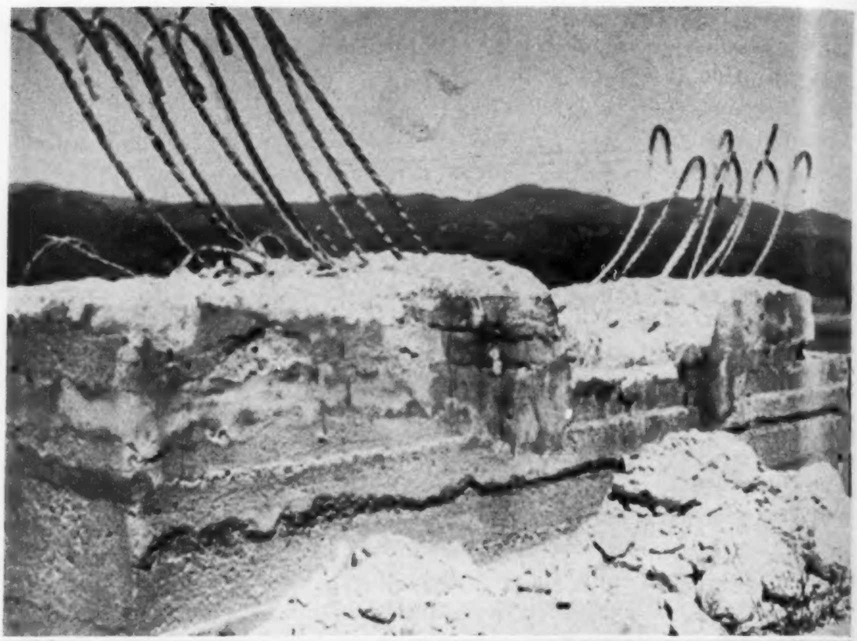
Various ideas were studied in an effort to eliminate the breathing caused by the sudden escape of entrained air creating periodic surges from the water impact in filling the escaped air void. A large concrete surge box was designed, based on experimental data on the rate of rise of air bubbles, to prohibit the entrained air from reaching the steel pipe section. A scale model of the surge box (Fig. 13) was then constructed and tested at various stages of flow. The model results were encouraging and on the basis of these showings two of the surge boxes were constructed at the head of the larger siphons, Jawbone and Soledad (Fig. 14). Although the results were not perfect, a substantial improvement in the properties of the pipe was effected.

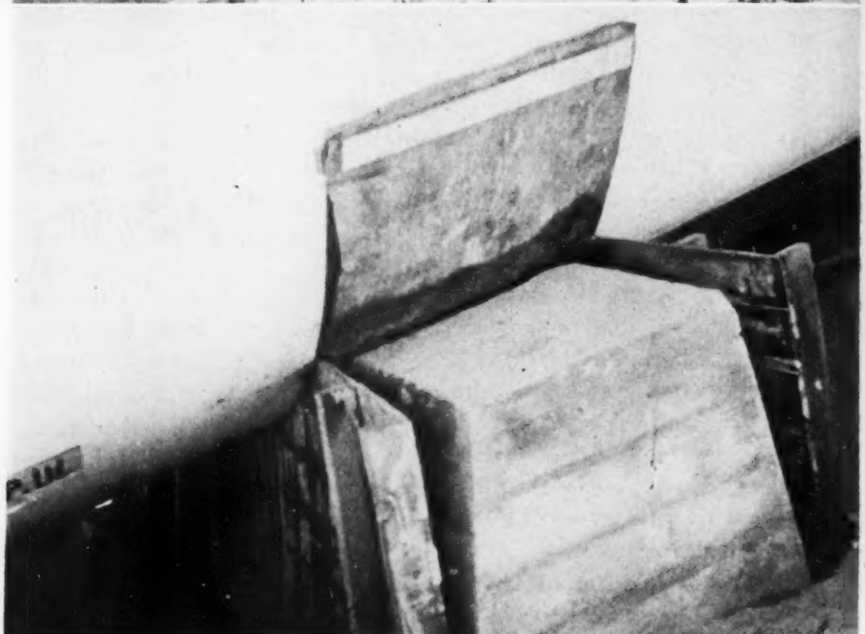
Preparations for Replacement

Work of removing the old steel where it was above the ground did not present any particular problem with the modern cutting torch (Fig. 15). The contractor endeavored to remove the plate in the most rapid manner and still salvage it in a condition that would be most useful and easily handled. Cuts on top of the siphons followed the riveted seams (Fig. 16). Side cuts were generally on a straight line halfway from top to bottom (Fig. 17), the bottom half being removed without further cutting. The demolition was performed in approximately 30-ft. lengths of the siphons.

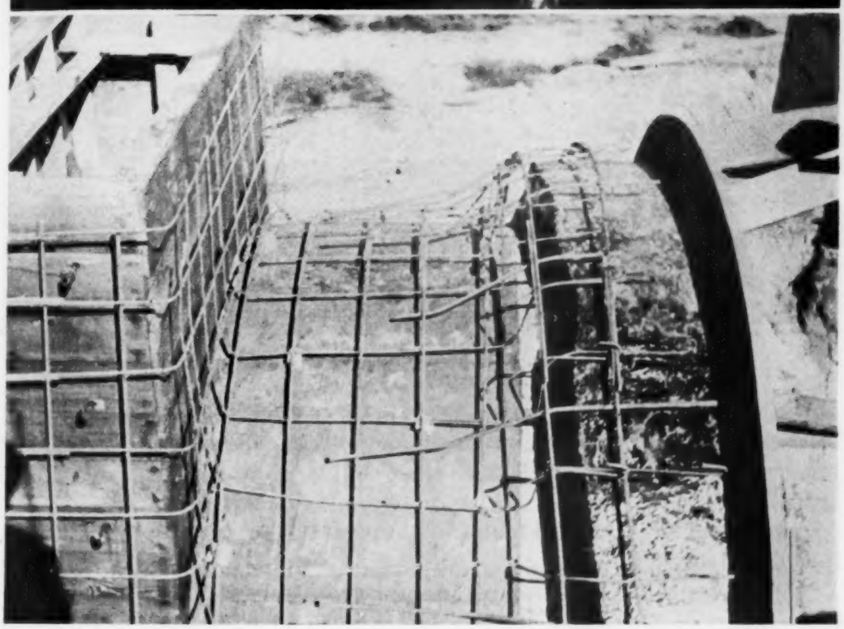
Considerable attention was given to the condition of the old piers, the plan being to utilize as many of them as possible. Where their condition was questionable, however, they were replaced. In most instances, because of the different sizes of pipe used on the new sections, it was necessary to reconstruct the top portion of the piers in order to conform to the new diameters. Insofar as possible, the old pier was utilized, including the original reinforcing steel, in rebuilding the upper portion of the pier (Fig. 18).

As a general rule the original piers formed a cradle of 120° of the pipe shell. The reconstructed piers were standardized to cradle 90° of the pipe, it having been found by experience that the higher piers were broken due to the breathing and flattening of the pipe when not under pressure. There was also a tendency to buckle the pipe upon flattening by the higher portions of the pier if it withstood the stresses and did not break before buckling the steel. Where the pipe is in contact with the piers, the coating is protected by two layers of 30-lb. asphalt roofing felt inserted between the pipe and the pier (Fig. 19). New piers were constructed as determined necessary by the engineer in the field. In some instances new intermediate piers were constructed where the original span was evidently excessive, as evidenced by buckling of the old pipe.



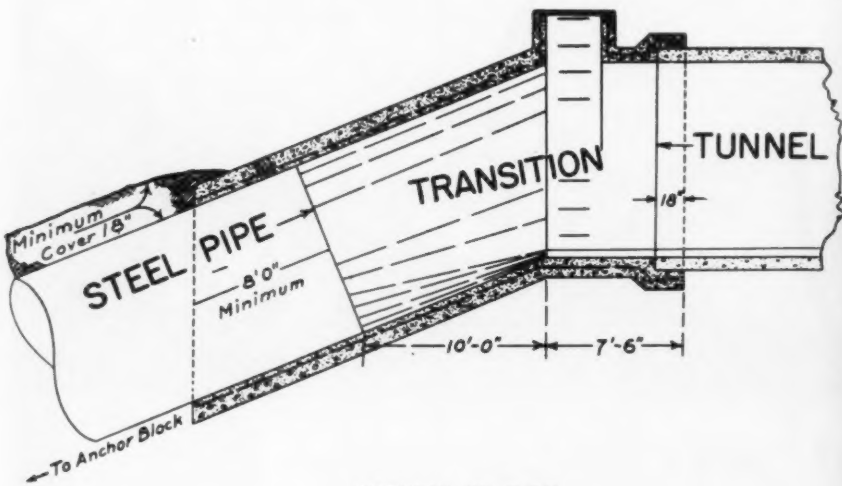


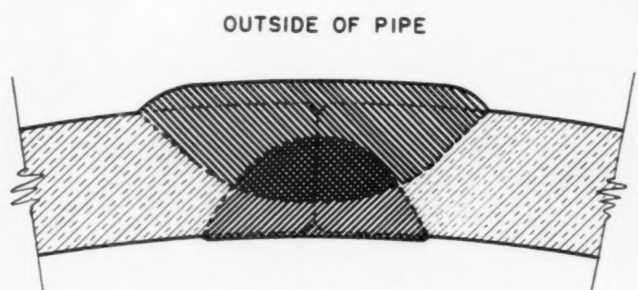
Top—Fig. 18. Demolished Top of Old Pier; showing intact reinforcing steel
Bottom—Fig. 19. Pipe Protection on Pier



Top—FIG. 20. Reinforcing Cage at Anchor Block
Bottom—FIG. 21. Joint Between Transitional Structure and Conduit

Anchor blocks designed to withstand stresses within a temperature range of 60° F. were constructed at all angles on the new pipe. Each anchor was cast in one continuous operation up to a construction joint formed at an elevation which allowed the pipe shell to be supported 40° on each side of the center-line at the bottom (Fig. 20). After the pipe was filled and while under full water head, the anchor block was completed in one continuous





Top—FIG. 22. Cross-Section of Concrete Transitional Structure
Bottom—FIG. 23. Cross-Section of Longitudinal Weld of Pipe; showing depth of penetration

operation and the pipe held under full head until the concrete had attained the desired strength.

Normal transitional structures are approximately 20 ft. in length, consisting of a warped section 10 ft. in length and collars around the tunnel or conduit section and the steel pipe (Fig. 22). In each transition a manhole was constructed for access to the structure. Connection with the pipe was made by an 8-ft. collar poured around the cleaned metal with grout

pipes installed so that all voids between pipe and concrete could be filled subsequent to pouring of the transition. Connection with the old tunnel or conduit section consisted of a 24-in. collar (Fig. 21). A coal-tar waterproofing compound was applied to the old section over which the reinforced concrete collar was poured.

Steel Pipe Specifications

Steel pipe for the new aqueduct siphon sections was fabricated and coated in a plant near Los Angeles. All steel pipe conformed to the requirements of "A.W.W.A. Standard Specifications for Electric Fusion Welded Steel Water Pipe of Sizes 30 Inches and Over—7A.3-1940."

FIG. 24. Spray-Gun Application of Coal-Tar Primer

Diameters of the pipe were $8\frac{1}{2}$ ft., 10 ft. and $10\frac{1}{4}$ ft. Lengths of sections were 30 ft. Plate was $\frac{3}{8}$ in. thick and made in accordance with "A.S.T.M. Specification, Designation A-78, Grade B." Ends of pipe were prepared with a slip-joint for field welding. Each section had three longitudinal seams and there were no girth seams. Elbows, bends and short sections for closure were completely fabricated in the plant, eliminating the necessity for field cutting.

The usual methods of manufacturing pipe were employed in planing of plate, lap-breaking, rolling, tack-welding and hydrostatic testing. Bells were prepared by pressing to shape, sections approximately 6 in. long, progressively around the circumference of the pipe.

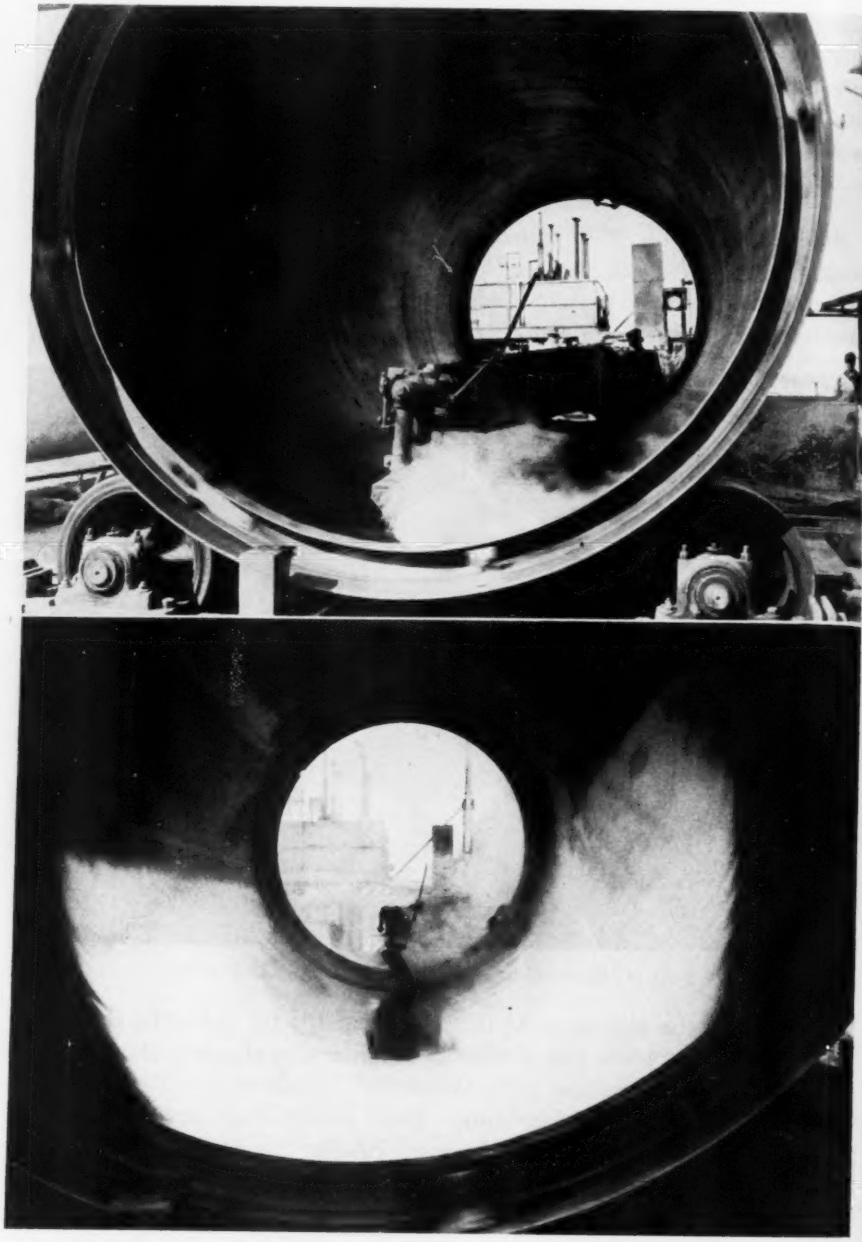


FIG. 25. Retracting Weir for Application of Lining: *Top*, At Start of Pour; *Bottom*, At End of Travel

The "Union Melt Process" of welding was used in making longitudinal welds and all of these welds were double-butt welds (Fig. 23). The outside welds were first made on the automatic welding machine. The inside of the pipe was then chipped out along the seam to clean weld metal. An inside weld was then made with the automatic welding machine.

In the welding process at the fabricating plant no backing-up bar was used. To prevent burning through the plate on the first weld, the amperage and voltage controls, as well as the carriage speed, were regulated to obtain a 75 per cent penetration. A substantial overlap of welding areas resulted by following this procedure.

In examining mill test reports of steel plate, the chemical analysis revealed a low, as well as uniform, carbon content. Physical tests indicated a high yield point and ultimate strength higher than the maximum limit in the specifications. Tests of the welded joint showed the yield point and ultimate stress to be well above the maximum requirements of the plate.

Protective Coatings and Linings

As has previously been discussed, the original pipe line was subjected to adverse forces, which were considered in the selection of proper pipe protection. The contract required enameling the inside of pipe lines and the outside of buried pipe lines with coal-tar enamel. Exposed sections were to be painted with a coat of synthetic red lead primer, to be followed with a coat of synthetic white enamel and a finish coat of aluminum paint. All material and application procedures conformed to the requirements of the "A.W.W.A. Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over—7A.5-1940."

At the plant, sections were lined and coated with coal-tar enamel, or lined with coal-tar enamel and painted on the outside with red lead and white enamel, as required. Pipe sections were cleaned by manual grit blasting. This was followed by the application of coal-tar primer by spray gun (Fig. 24). Type "A" coal-tar enamel was used throughout the work. The lining was cast centrifugally by the retracting weir method (Fig. 25). The introduction of the cantilever arm, the spinning of the pipe, flowing of enamel over the weir and the resulting smooth mirror-like surface are always spectacular.

The equipment employed to apply coal-tar enamel coating over the primed surfaces on the outside pipe section, was the conventional traveling tar kettle type (Fig. 26). This equipment is provided with a movable arm which permits the operator to make certain manual changes in the application of the coal-tar enamel. All specials were enameled by hand-daubing, small electrically heated kettles being used to heat the enamel (Fig. 27).

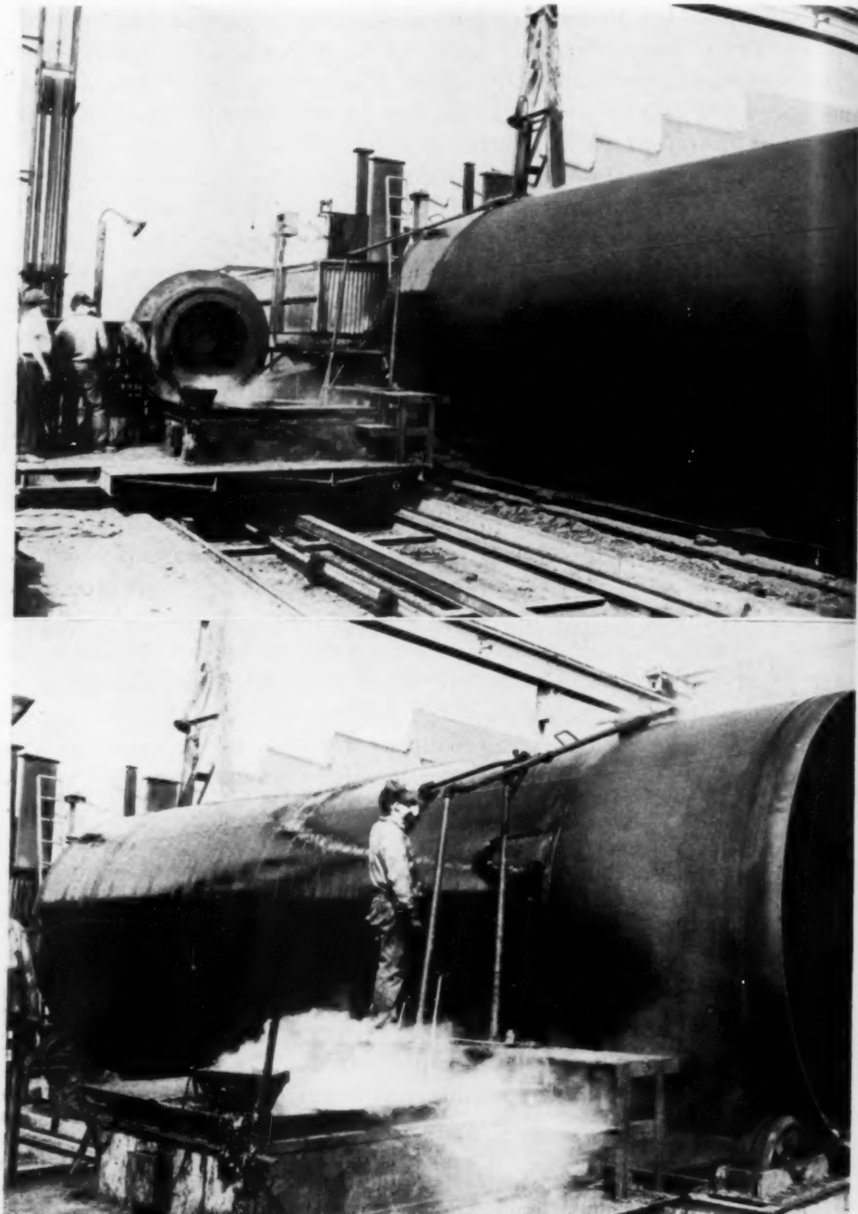
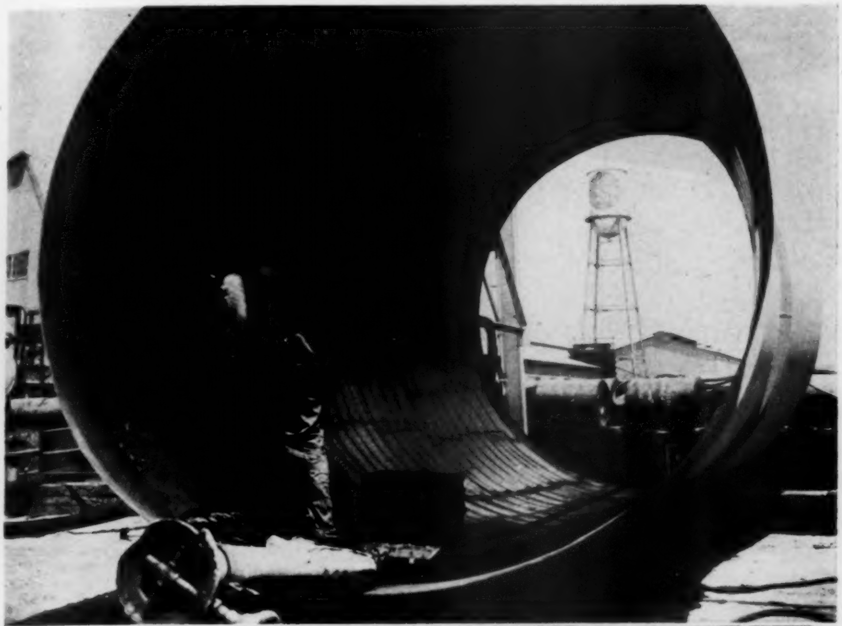
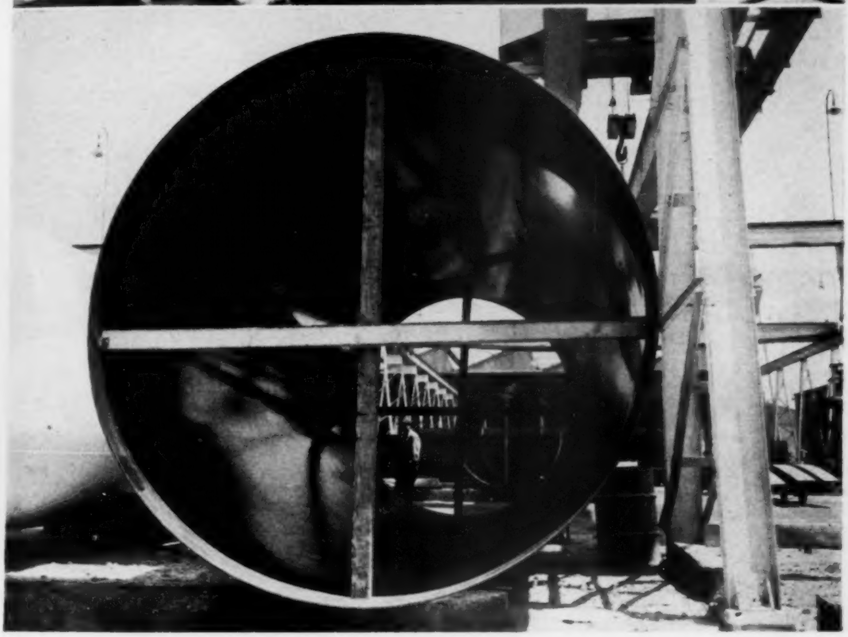


Fig. 26. Outside Traveling Kettle for Application of Coal-Tar Enamel Coating: *Top*, At End of Pipe; *Bottom*, At Center of Pipe





Top—FIG. 27. Enameling Specials by Hand-Daubing
Bottom—FIG. 28. Cross-Bracing of Pipe for Shipping and Erection

Top—Fig. 29. Pipe Loaded on Truck and Trailer
Bottom—Fig. 30. Crane at Top of Siphon

Prior to whitewashing, the enameled thickness was measured by the electrical thickness gage and the holiday detector brush was used in checking all surfaces to detect pin holes and bare spots in the enamel lining and coating. The synthetic red lead primer and synthetic white enamel paint were applied by spraying and 24 hr. drying time was allowed between coats.

Transportation and Handling of New Pipe

Two small but important details in connection with the fabrication and erection should be pointed out: (1) cross-bracing and (2) heating of manual welds. In cross-bracing pipe for shipping and erection (Fig. 28), the common practice previously had been to weld angles to the inside of the pipe and drive spikes through holes in the upright leg of the angle into the wooden struts. The spikes proved unsatisfactory. When lag screws were employed these struts held up during the shipping and erection operations. Light welds fastening angle clips were found desirable, inasmuch as some damage resulted to the enamel from the flame-cutting operations in removing heavily welded clips. In view of the fact that the weld metal is much stronger than the parent metal, if heavily welded clips are knocked off with a sledge hammer a large piece of steel plate will be torn out, requiring subsequent patching. To prevent blistering of the enamel it was found necessary to heat with a blow torch to approximately 500° all manual welds made repairing structural defects in the plate and attaching angle clips to the pipe.

The pipe was trucked from Los Angeles to the job site (Fig. 29) and the contract specified that it be stored at the required locations before the aqueduct was shut off to permit starting of the work. There is an interesting contrast between the types of equipment employed on this project when compared to that used during the original construction.

With the exception of the south end of the Jawbone Siphon, which is on an extreme slope, making it impossible to utilize equipment of the modern design, all pipe was handled, from the time of arrival on trucks, by cranes of the "Northwest" type (Fig. 30). Since the original construction, roads had been built for the purpose of facilitating maintenance and operation, so that almost every point on the lines was available by automotive equipment; hence, with the combination of trucks and cranes, it was possible to place the new pipe in its final location with very little handling.

Hoisting of the pipe sections was performed by use of cable slings covered with rubber hose (Fig. 31). This method proved very satisfactory and caused very little damage to the pipe coating. On warm days there was a tendency for the slings to gouge into the coating but the coating disturbance was nominal and easily patched.

As the sections were lowered by the crane they were stabbed or joined to the preceding pipe. In stabbing, the top of the bell was slipped over the

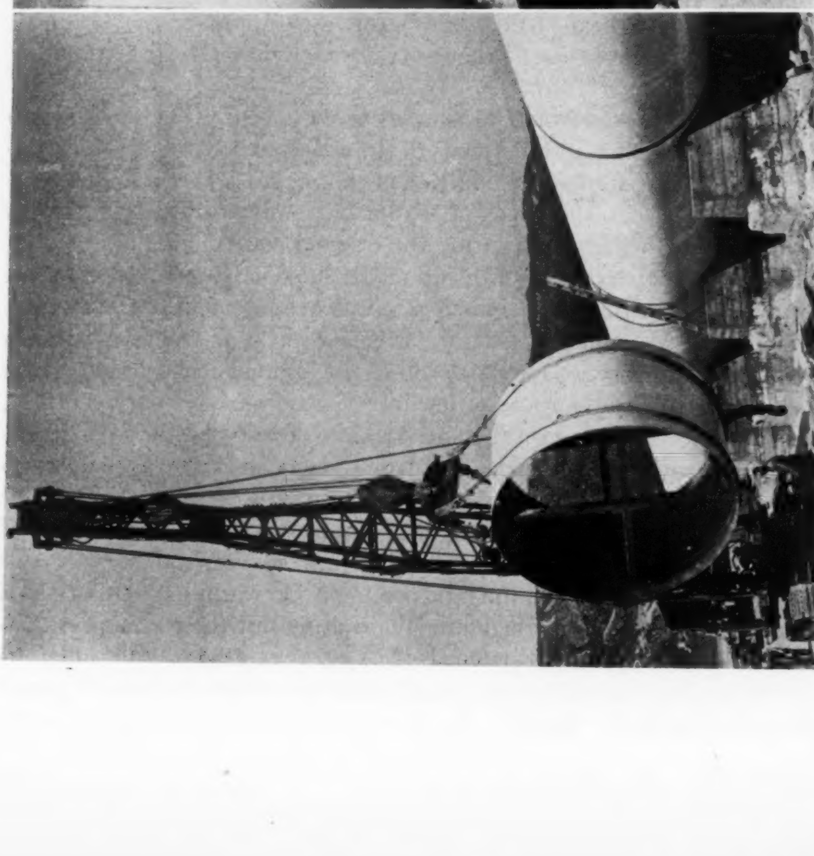


Fig. 31. Crane Holding Closing Section of Pipe

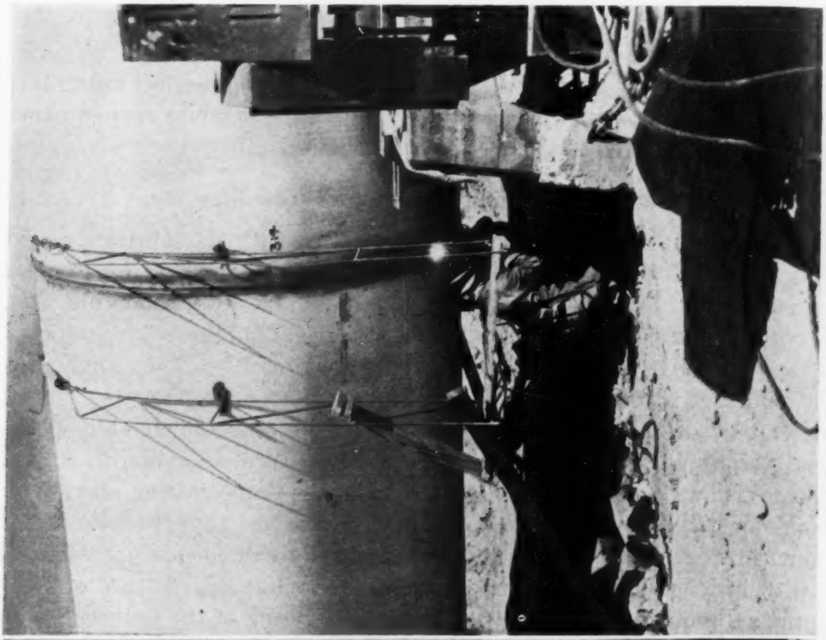
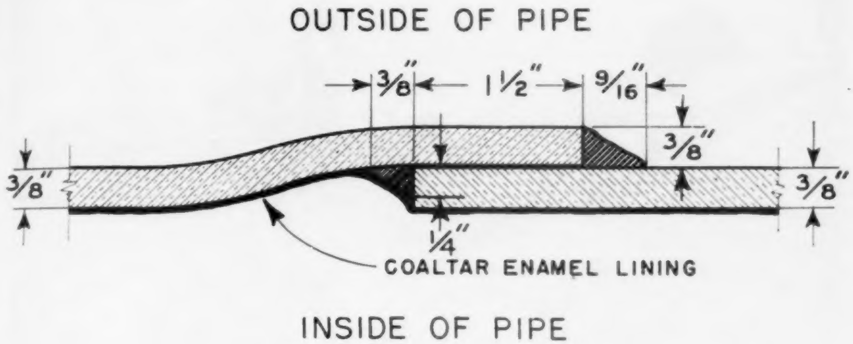
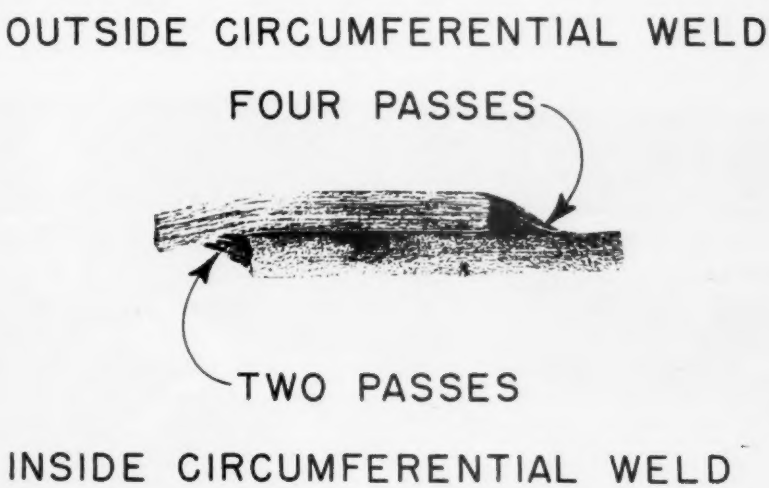


Fig. 32. Portable Staging Unit for Welders

spigot for a distance of $1\frac{1}{2}$ in. and the two sections were immediately tack-welded and joined on the top of the pipe. This tack-weld served as a hinge for the final lowering of the pipe. Five additional tack welds, each approximately 4 in. long, were then evenly spaced around the circumference and held the pipe until final welds were completed.





Top—FIG. 33. Slip Joint for Field Welding
Bottom—FIG. 34. Section Through Weld of Slip Joint for Field Weld

Jointing and Welding Specifications

At the pipe fabricating plant, the slip joint was made by belling one end of the pipe sufficiently to obtain a "glove-fitting" lap joint approximately $1\frac{1}{2}$ in. long (Fig. 33). The practice of the Water Bureau, for steel pipe lines up to 6 ft. in diameter, has been to require one circumferential weld at each

Top—FIG. 35. Caterpillar Tractor Removing Old Material
Bottom—FIG. 36. Portion of Dead Man Siphon

joint. On the aqueduct siphons, two circumferential welds were required at each joint— a full weld on the outside and a seal weld on the inside.

The advantage of the slip joint is very apparent. It provides structural continuity and permits the entire inside surface to be completely protected with coal-tar enamel. In addition, this joint serves as an aid in the laying operations.

All field welds were made by the electric-shielded arc method and the specifications required that all circumferential welds be made in a downward direction. To accomplish this and to obtain the size of weld desired, four passes on the outside of the pipe and two or three passes on the inside of the pipe were necessary.

Due to the size of pipe it was necessary to construct a light portable staging unit for the welders (Fig. 32). The conventional type of welding machines was used on the work. All welders were qualified, under paragraph U69 of the "A.S.M.E. Code for Unfired Pressure Vessels," and were required to make test welds in a downward direction in the same position in which the work was to be done. In making an outside circumferential weld the men usually worked in pairs, the time required to complete the weld being 8 hr. In making an inside circumferential weld, one man usually worked alone, the time required to complete the weld being 8 hr. The welding rod used was selected for downhill welding, and was determined by tests conducted by Water Bureau Engineers.

The desirability of specifying welding in a downward direction is readily seen in examining the joint (Fig. 34). Due to the proximity of the welds, there is a tendency for the area to be over-stressed unless the welds are annealed. This condition is eliminated to a great extent by the successive passes required in making the downhill welds.

Another specification requirement was that fillet welds should have full penetration into the corner of the fillet and should be obtained with a minimum cutting back of the edge of the outside plate. These conditions are easier to fulfill and inspection is facilitated by requiring downhill welding.

Enameling of Field Joints

Enameling of the field joints followed very closely the field welding. Considerable field enameling was required inasmuch as the pipe was left bare a distance of from 12 to 14 in. from the ends in the enameling operations at the plant. The equipment used in the field coating of enamel permitted the usual application procedure of buffing, welding, priming and enameling. The time required for a crew to complete the enameling of a field joint was approximately an hour.

FIG. 37. Rear-End View of Specially Constructed Dolly

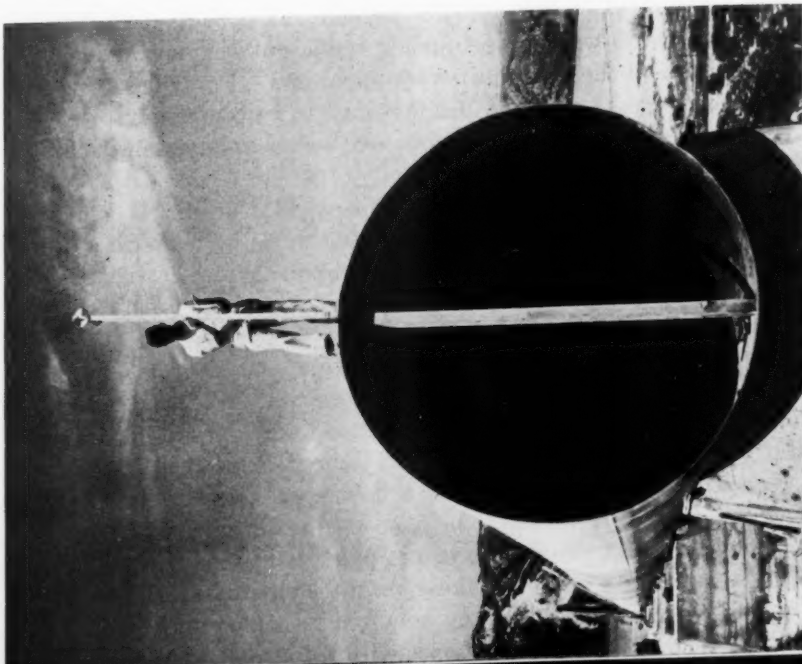


FIG. 38. Establishing Line and Grade for New Pipe Installation

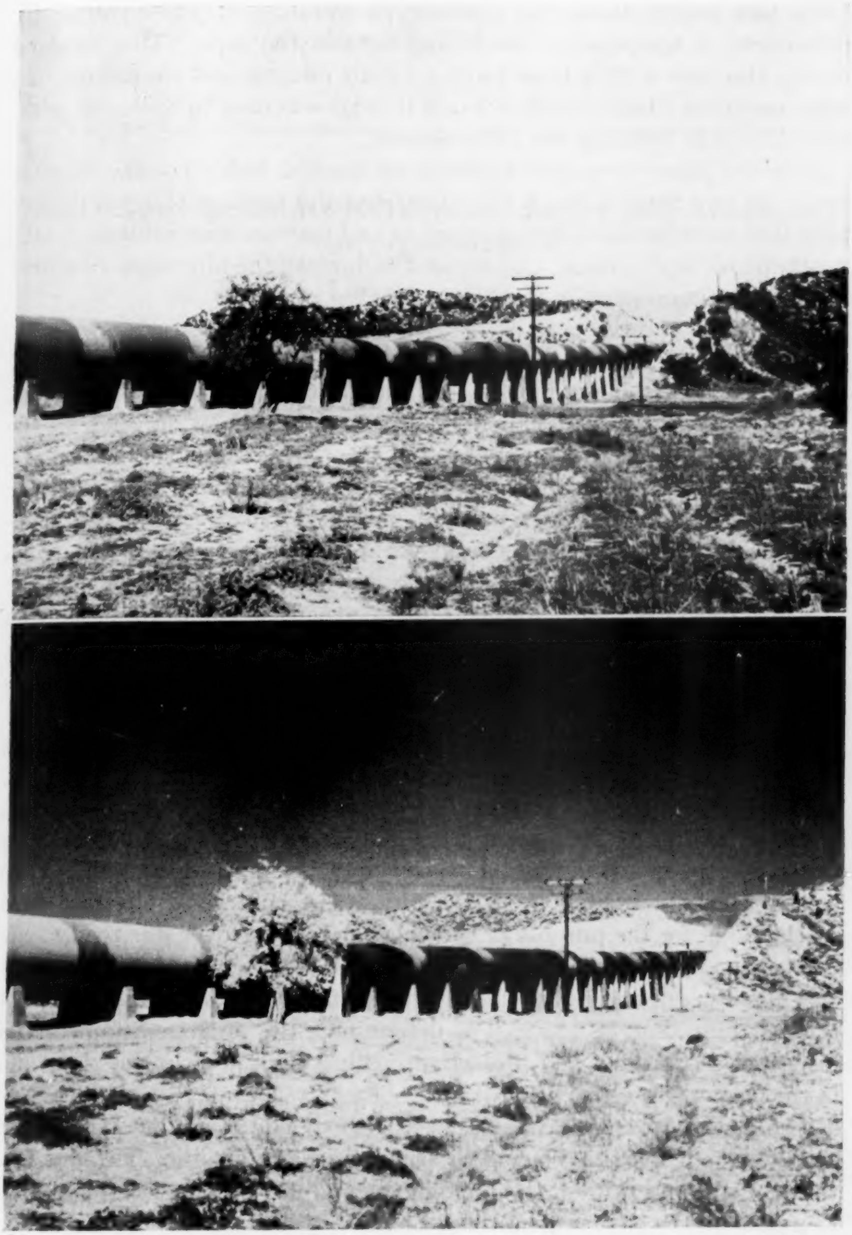


FIG. 39. Camouflaged Siphon: *Top*, Photographed With Ordinary Film; *Bottom*, Photographed With Infra-Red Film

On this project there was considerable sweating of joints caused by differences of temperature inside and outside the pipe. This required drying the pipe with a blow torch prior to priming and enameling. In some instances a heavy blanket 3 or 4 ft. wide was used to cover the joint, this effectively reducing the condensation.

After the joints were coated, they were checked with a holiday detector brush for any flaws or pin holes. Outside paint surfaces of exposed pipelines that were damaged during handling and erection were retouched with synthetic red lead primer. All exposed surfaces of the pipe received a final coat of aluminum paint in the field.

Pipe-Laying Methods

On all siphons the new pipe was laid uphill with bell ends down, so that the remaining portion of siphon would support the new sections on the slope until final closure and anchor block support were completed. The final closing joints were left at the top and were not welded until the entire siphon was filled with water up to such joint. Where long straight sections existed between angles a supplementary closing joint was left to be welded as the water was brought up in the pipe. As installation of the new pipe progressed, the movement due to expansion and contraction from temperature variations was pronounced. By this method of making closing joints, maximum expansion was obtained and the structures were stabilized with the stresses close to the final operating conditions.

The modern caterpillar tractor was utilized principally in the backfilling operations and in some instances in the removal of the old steel (Fig. 35). In the case of the south portion of Jawbone Siphon previously mentioned, the road leading to that point from the canyon contained many sharp curves so that it was impossible to transport the pipe up the slope in the trucks which brought it from the city. The contractor constructed a special dolly for the purpose of carrying the sections over this road, using the tractor as motive power (Fig. 37).

Water Bureau engineers established line and grade for the installation of the new pipe (Fig. 38), as well as determining the progress attained, and inspected the welding and protective coating work both in the plant and in the field.

The current events have not been without effect on the siphons, for through them water is flowing to army and navy facilities, airplane factories, munitions works, shipbuilding plants and other allied industries, as well as to the civilian population of Los Angeles. The shiny aluminum colors have now been replaced with dramatic camouflage colors (Fig. 39). Camouflage paints have been selected as to effectiveness of color and infrared reflecting properties, as well as heat reflecting properties.

Calcium Carbonate Saturation Index and Alkalinity Interpretations

By T. E. Larson and A. M. Buswell

THE calcium carbonate solubility equilibrium is highly important in many phases of water chemistry. It is directly associated with scale formation in many types of equipment, from tea kettles to boiler feed water heaters, and with incrustation of well screens, filter sand, meters and water taps. In physiological chemistry it is significant in relation to bone calcification and to blood equilibriums. In geochemistry the deposition of carbonates is also related to this equilibrium.

The equilibrium balance is affected by many natural reactions in water, before, during or after the process of treatment. Photosynthesis in surface supply reservoirs removes CO_2, resulting in a pH increase which has been known to precipitate $CaCO_3$. Aeration of well waters whether from mechanical means or mere exposure to air alters the equilibrium by loss or absorption of CO_2. Treatment with coagulants always changes the free CO_2. "Air binding" in filters, due to drop in pressure, tends to draw out CO_2 and shift the equilibrium. Chlorine treatment and de-aeration are not without effect. Anti-corrosion treatment whether by lime, soda ash, silicates, chromates or phosphates more or less affects this equilibrium. Bacterial growths in the mains may either consume CO_2, or, in some cases, produce CO_2, directly or indirectly. Bacterial action can convert the basic ammonium ions into acidic nitrite or nitrate ions. Corrosive action itself has a direct influence by the production of hydroxyl ions which alter the equilibrium, significantly to precipitate $CaCO_3$ at the point of corrosion in hard high alkalinity waters. A change in temperature naturally changes the status of the relationship.

Many other conditions could be listed, but these serve to illustrate the importance of the subject. The reverse consideration is perhaps of still greater importance. How does this equilibrium affect the reactions and treatments mentioned? In many cases, attention to, and control of, this

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equilibrium will aid or increase the effectiveness of the treatments and the resultant quality of the water.

Various equations have been proposed for calculating the carbonate equilibrium, ranging from the early simple relation of Tillmans (1) and Greenfield and Baker (2) to the more rigorous work of Johnston (3, 4), Langelier (5) and others. None of these equations is sufficiently fundamental to be applicable over wide ranges of temperature and concentrations and, even in the average range, their apparent applicability is frequently due to compensating errors. For the sake of comparison, the calculated saturation pH of a water of 20.0 ppm. Ca, 12.2 ppm. Mg, 300 ppm. alkalinity (as $CaCO_3$), 92 ppm. Na, and 320 ppm. residue at 25°C. is 7.8 by the Langelier calculation and 7.57 by corrected constants. At 80°C. the respective saturation pH values are 6.9 and 7.07. Likewise, for a water of 41.3 ppm. Ca, 16.0 ppm. Mg, 352 ppm. alkalinity (as $CaCO_3$), 267 ppm. Cl, 20 ppm. SO_4, 230 ppm. Na, and 800 ppm. residue, the calculated saturation pH is 7.6 at 25°C. by the Langelier calculation but 7.20 if the corrected constants are used. At 80°C. the respective saturation pH values are 6.7 and 6.69.

This discussion, therefore, is intended to extend the general applicability of the saturation equation without including prohibitively complicated considerations. This permits accumulation of more accurate data for comparative purposes, not only for various plants, but also for various points in the distribution system supplied by the same plant.

The constants involved in developing a saturation equation represent the law of mass action applied to the following equilibriums:

$$H_2O \rightleftarrows H^+ + OH^- \qquad (1)$$

$$K_w = (H^+)(OH^-) = \gamma_{H^+}[H^+]\gamma_{OH^-}[OH^-] \qquad (1a)$$

$$K'_w = [H^+][OH^-] \qquad (1b)$$

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^- \qquad (2)$$

$$K_1 = \frac{(H^+)(HCO_3^-)}{(H_2CO_3)} = \frac{\gamma_{H^+}[H^+]\gamma_{HCO_3^-}[HCO_3^-]}{CO_2} \qquad (2a)$$

$$K'_1 = \frac{[H^+][HCO_3^-]}{CO_2} \qquad (2b)$$

$$HCO_3^- \rightleftarrows H^+ + CO_3^= \qquad (3)$$

$$K_2 = \frac{(H^+)(CO_3^=)}{(HCO_3^-)} = \frac{\gamma_{H^+}[H^+]\gamma_{CO_3^=}[CO_3^=]}{\gamma_{HCO_3^-}[HCO_3^-]} \qquad (3a)$$

$$K'_2 = \frac{[H^+][CO_3^=]}{[HCO_3^-]} \qquad (3b)$$

$$CaCO_3 \rightleftarrows Ca^{++} + CO_3^{=} \quad \ldots\ldots (4)$$

$$K_s = (Ca^{++})(CO_3^{=}) = \gamma_{Ca^{++}}[Ca^{++}]\gamma_{CO_3^{=}}[CO_3^{=}] \quad \ldots\ldots (4a)$$

$$K_s' = [Ca^{++}][CO_3^{=}] \quad \ldots\ldots (4b)$$

where parentheses represent activities and brackets represent concentrations in moles per liter.

The activity concept assumes complete dissociation of salts in dilute solutions, a condition which obeys the law of mass action only at infinite dilution. Deviations from the ideal condition are corrected for by considering "effective" concentrations or activities. The activity coefficient γ_x may be defined as a measure of the extent of deviation, or the ratio of the "effective" concentration to the actual concentration, $\gamma_x = (x)/[x]$. Hence at infinite dilution, the activity is equal to the concentration and the activity coefficient is 1.0.

The activity coefficient, γ_x, may be calculated by:

$$\log \gamma_x = -.5v_x^2\sqrt{\mu}/(1 + A\sqrt{2\mu}) \quad \ldots\ldots (5)$$

where v_x is the valence of x and μ is the ionic strength of the solution. The latter is defined as one-half the summation of the productions of the molal concentrations of the ions in solution and the square of their respective valences, $\frac{1}{2}\Sigma m_x v_x^2 + m_y v_y^2 + \cdots$. In general, the simplified expression (5) for natural waters of less than 500 ppm. mineral content may be used, $\mu = 0.000025$ times the total mineral content.

A is a constant dependent on ionic diameter and is calculated from the experimental data for various equilibriums. In water works practice this value may generally be taken as 1.0 for simplicity, although this may be quite far from the correct value.

Since total alkalinity (in equivalents per liter) is equal to:

$$[\text{Alky.}] + [H^+] = 2[CO_3^{=}] + [HCO_3^-] + [OH^-] \quad \ldots\ldots (6)$$

then:

$$[CO_3^{=}] = \tfrac{1}{2}[\text{Alky.}] - \tfrac{1}{2}[HCO_3^-] \quad \ldots\ldots (7)$$

when $[H^+]$ and $[OH^-]$ are too small to be significant (pH < 10.5). From Eq. 3b:

$$[CO_3^{=}] = \frac{K_2'[HCO_3^-]}{[H^+]} \quad \ldots\ldots (8)$$

and combining Eqs. 7 and 8:

$$[HCO_3^-] = \frac{[\text{Alky.}]}{1 + 2K_2'/[H^+]} \quad \ldots\ldots (9)$$

Combining Eqs. 8 and 9:

$$[CO_3^=] = \frac{K_2'[\text{Alky.}]}{[H^+](1 + 2K_2'/[H^+])} \quad \text{(10)}$$

and substituting in Eq. 4b:

$$K_s' = [Ca^{++}] \frac{K_2'[\text{Alky.}]}{[H^+](1 + 2K_2'/[H^+])} \quad \text{(11)}$$

If $-\log K = pK$, then at saturation equilibrium:

$$p[H^+] = pK_2' - pK_s' - \log[Ca^{++}] - \log[\text{Alky.}] + \log(1 + 2K_2'/[H^+]) \quad \text{(12)}$$

The last term may be omitted if the pH is below about 9.0, but involves a correction of 0.05 to 0.5 as the pH increases from about 9.0 to 10.3.

This equation in the various forms, as suggested by Tillman (1), Langelier (5), and Strochecker (6), has served a very useful purpose. In many cases, however, it is not sufficiently rigorous. Its shortcomings have not always been detected, since compensating errors frequently give apparent checks with experimental data when in reality the results are incorrect. The purpose of the present paper is to correct the activity factors for salinity in accordance with the most recent data and to indicate the correct constants at various temperatures.

Salinity Corrections

The second ionization constant, K_2, for carbonic acid is commonly taken to be that indicated by MacInnes (7) and has been considered authentic until recent date. The value of K_2', however, has been obtained (5, 8) by $pK_2' = pK_2 - .382\sqrt{\mu}$. This is contrary to the experimental data and was used by MacInnes for extrapolation purposes only. A closer approximation for these data would be $pK_2' = pK_2 - 1.382\sqrt{\mu}$. More recently Harned and Sholes (13) have provided a more correct value for K_2, whereby K_2' is calculated by $pK_2' = pK_2 - \dfrac{2\sqrt{\mu}}{1 + 1.4\sqrt{\mu}}$.

The first ionization constant, K_1, as commonly used, is likewise from MacInnes (7). The value of K_1', however, has been obtained (8) by $pK_1' = pK_1 - .119\sqrt{\mu}$. This also is contrary to the experimental data in which this equation merely represents that used for extrapolation purposes. A more nearly correct equation should be $pK_1' = pK_1 - \dfrac{\sqrt{\mu}}{1 + 1.4\sqrt{\mu}}$. More recently Shedlovsky and MacInnes (10) have indi-

cated close agreement with the above constant and also show the variation with temperature.

The ionization constant for water K_w should be taken from the excellent work of Harned and collaborators (9, 11) wherein $pK'_w = pK_w - \dfrac{\sqrt{\mu}}{1 + 1.4\sqrt{\mu}}$.

The solubility product for calcium carbonate, K_s, is that of Johnston and Frear (3), and K'_s is assumed to vary as $pK'_s = pK_s - 4\sqrt{\mu}$ (5). This is contrary to the experimental data used in the determination of this constant (3, 16). It appears that K'_s of the experimental data would more nearly be approximated by $pK'_s = pK_s - \dfrac{4\sqrt{\mu}}{1 + 3.9\sqrt{\mu}}$ (see Eq. 13 and footnote).

Temperature Corrections

The temperature correction for the solubility product of calcium carbonate is given by Langelier as $pK'_{s(t)} = pK_{s(25°C.)} - \log r$ (5) and later corrected to $pK'_{s(t)} = pK'_{s(25°C.)} - 2 \log r$ (12). Neither of these expressions is correct. These were taken from the Johnston and Frear summary (3) which gives the value, r, as the ratio of the "solubility" (not the solubility product) at t°C. to that at 25°C. Since calcium carbonate hydrolyzes as follows:

$$2CaCO_3 + H_2O \rightleftarrows 2Ca^{++} + xCO_3^{--} + yOH^- + yHCO_3^-$$

only the CO_3^{--} of the alkalinity present can be used in the solubility product calculations. At 16°C. at equal $[OH^-]$ and $[HCO_3^{--}]$, the $[CO_3^{--}]$ is only 46 per cent of the total alkalinity (4). Therefore, the value, r, should not and cannot be used as the ratio of the "solubility product" at t°C. to that at 25°C.

With the recent data on the temperature variation for K_1 (10), and K_2 (13) as well as for K_w (9), it is now possible to calculate correctly the temperature variation for K_s from 0–50°C. It would be desirable to have further data for K_1 and K_2 to 70 or 85°C.

Using the data of Johnston and Frear (3) and applying:

$$K'_s = \frac{\gamma_{Ca^{++}}\gamma_{HCO_3^-}[Ca^{++}][HCO_3^-]^2 K'_2}{PK'_1c} \quad \text{.............(13)}$$

from Eqs. 2b, 3b and 4b, or:

$$pK'_s = pK'_2 - pK'_1 - pP - pc + p[Ca^{++}] + 2p[HCO_3^-] + \frac{3\sqrt{\mu}}{1 + 4.86\sqrt{\mu}},$$

the average value for pK_s becomes 8.34 or $K_s = 4.55 \times 10^{-9}$. For these data pK_s' varies as $\frac{3\sqrt{\mu}}{1 + 4.86\sqrt{\mu}}$ *. This is assumed by analogy to the data by Shedlovsky and MacInnes on calcium chloride solutions (14). The data for c, the solubility of CO_2 at a partial pressure, P, of one atmosphere, was taken from Bohr (15). The values for K_1 and K_2 were taken from the more recent data presented in Table 1. It is interesting to note that the ratio of these values (9200) at 25°C. agrees remarkably well with that (9100) obtained by Walker, Bray and Johnston (16).

Also, using the data for K_1, K_2 and c (15), as given in the listed references, and the ratio of the calcium solubility, as given by Johnston (3), where $\log r = \frac{830}{T} - 2.78$, the variation of pK_s with temperature is calculated as given in Table 1.

Alkalinity Interpretation

It has been proposed (5, 8, 9), and correctly so, that free CO_2 and the forms of alkalinity be determined by calculation from the following equations:

Hydroxide concentration (as $CaCO_3$) (from Eq. 1b):

$$\text{ppm. } [OH^-] = 50{,}000 \frac{K_w'}{[H^+]} \qquad (14)$$

where $\text{pH} = \log \frac{1}{(H^+)} = \log \frac{1}{[H^+]} + \frac{.5\sqrt{\mu}}{1 + 1.5\sqrt{\mu}}$.

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* In the saturation equation as derived, however, $[Ca^{++}]$ and $[CO_3^{--}]$ are involved. Therefore K_s must vary as $\gamma_{Ca^{++}}$ and $\gamma_{CO_3^=}$. The equation for pK_s' can be obtained from the identity:

$$(Ca^{++})(HCO_3^-)^2 = (Ca^{++})(CO_3^{--}) \times \frac{(H^+)(HCO_3^-) \times (HCO_3^-)}{(CO_3^=)(H^+)}$$

Then:

$$\gamma_{Ca^{++}}\gamma_{HCO_3^-}{}^2 = \gamma_{Ca^{++}}\gamma_{CO_3^=} \times \frac{\gamma_{H^+}\gamma_{HCO_3^-}}{\gamma_{CO_3^=}} \times \frac{\gamma_{HCO_3^-}}{\gamma_{H^+}}$$

and:

$$\frac{3\sqrt{\mu}}{1 + 4.86\sqrt{\mu}} = \frac{4\sqrt{\mu}}{1 + A\sqrt{\mu}} - \frac{1\sqrt{\mu}}{1 + 1.4\sqrt{\mu}} \times 1$$

therefore:

$$pK'_{CaCO_3} = pK_{CaCO_3} - \frac{4\sqrt{\mu}}{1 + 3.9\sqrt{\mu}} \text{ (approx.)}$$

in the range where $\sqrt{\mu} = 0.05 - 0.1$.

Any deviation from the assumption concerning the equality of γ_{H^+} and $\gamma_{HCO_3^-}$ would cause only an insignificant error in the data for which K_s is to be used.

Bicarbonate concentration (as $CaCO_3$) (from Eqs. 6 and 8):

$$\text{ppm. } [HCO_3^-] = 50{,}000 \frac{\dfrac{[\text{Alky.}]}{50{,}000} + [H^+] - \dfrac{K'_w}{[H^+]}}{1 + \dfrac{2K'_2}{[H^+]}} \quad \ldots\ldots\ldots (15)$$

where [Alky.] = ppm. alkalinity (as $CaCO_3$).

Carbonate concentration (as $CaCO_3$) (from Eqs. 8 and 15):

$$\text{ppm. } [CO_3^=] = \frac{K'_2}{[H^+]} \times \text{ppm. } [HCO_3^-] \quad \ldots\ldots\ldots\ldots (16)$$

TABLE 1

Values for K_1, K_2, K_w and K_s

t°C.	$K_w \times 10^{14}$*	$K_1 \times 10^{7}$†	$K_2 \times 10^{11}$‡	$K_s \times 10^{9}$§
0	0.115	2.61	2.36	9.50
10	0.298	3.34	3.24	7.07
20	0.681	4.05	4.20	5.25
25	1.008	4.31	4.69	4.55‖
30	1.460	4.52	5.13	4.03
40	2.916	[4.85]¶	6.03	[3.06]
50	5.469	[5.05]	6.73	[2.37]
60	9.637	[5.08]	[7.20]	[1.83]
70		[5.00]	[7.51]	[1.38]
80		[4.84]	[7.55]	[1.06]

* See reference 9.
† See reference 10.
‡ See reference 13.
§ Recalculated from references 3, 16, 10, 13 and Eq. 13.
‖ Value is 4.86 in reference 3.
¶ Brackets indicate extrapolated values.

Free carbon dioxide concentration (as CO_2) (from Eq. 2b):

$$\text{ppm. } CO_2 = \frac{.88\,[H^+][\text{Alky.}]}{K'_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

$$\log CO_2 = \log \frac{.88}{K_1} + \log\,[\text{Alky.}] - \text{pH} - .5\sqrt{\mu} \quad \ldots\ldots (17a)$$

$$\log CO_2 = \log \frac{.88}{K'_1} + \log\,[\text{Alky.}] - \text{pH} + .5\sqrt{\mu} \quad \ldots\ldots (17b)$$

In these determinations care should be taken to note serious discrepancies which may arise in certain ranges from inconsistent use of hydrogen ion activity (H^+) or concentration [H^+] and appropriate constants. If pH is to be obtained at values greater than 10.0, it is advisable to standardize the glass electrode against a standard buffer solution in this range.

A glaring example of the fallacy of the simple methods for the calculation (17) of the forms of alkalinity is noted in Fig. 1. The pH on the left

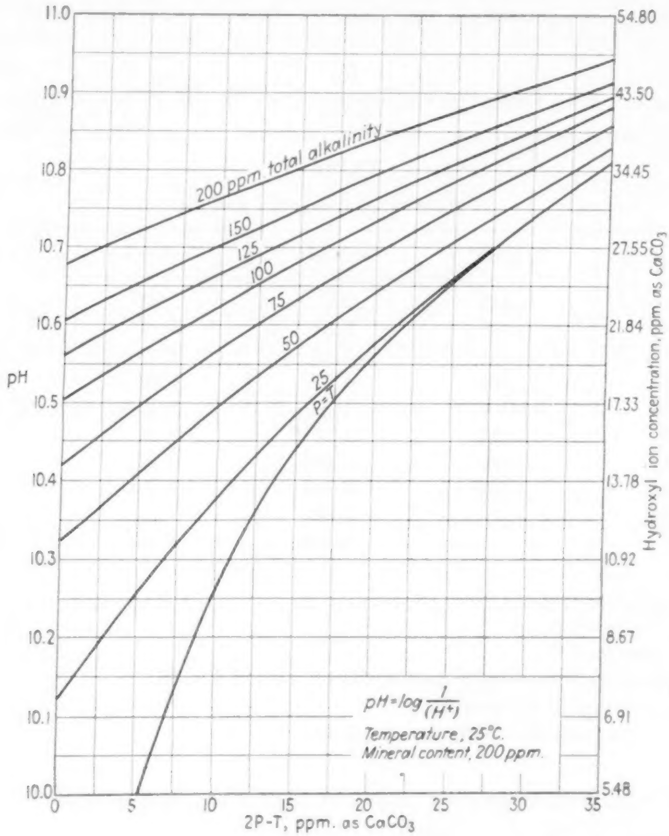

FIG. 1. Relation of "So-Called" Caustic Alkalinity to pH and [OH^-]

and the corresponding true hydroxyl ion concentration on the right may be compared with the "$2P - T$" values (caustic alkalinity) indicated on the abscissa for the various curves for total alkalinity. In this connection it is evident that the federal drinking water standards committee should limit causticity to a definite hydroxyl ion concentration rather than to a given value for causticity. Since the hydroxyl ion concentration

varies considerably for a small error in pH in this range and since the pH varies appreciably with temperature and total mineral content, a constant hydroxyl ion concentration may be represented by $P = aT + b$, where a and b are constants, dependent on the limitation on the hydroxyl ion concentration, and where P and T represent the phenolphthalein and methyl orange alkalinities.

It may be of interest to boiler water analysts that the true $[OH^-]$ and pH can be calculated from the phenolphthalein and methyl orange alkalinities or their more accurate equivalents from strontium chloride or barium chloride methods, providing the boiler water is of less than about 1,200 ppm. mineral content:

$$[OH^-] = \sqrt{\left(\frac{K'_w}{2K'_2} \times 10^4\right)^2 + (2T - P)\frac{K'_w}{2K'_2} \times 10^4 \times \left(\frac{2P - T}{2}\right)^2}$$

$$+ \tfrac{1}{2}(2P - T) - \frac{K'_w}{2K'_2} \times 10^5 \ldots\ldots\ldots\ldots (18)$$

$$pH = pK'_w + \log\left[\sqrt{\left(\frac{K'_w}{K'_2} \times 10^4\right)^2 + \left(\frac{2T - P}{10}\right)\frac{K'_w}{K'_2} \times 10^4 + \left(\frac{2P - T}{20}\right)^2}\right.$$

$$\left. + \frac{2P - T}{10} - \frac{K'_w}{K'_2} \times 10^4\right] - 4.00 + \frac{.5\sqrt{\mu}}{1 + 1.5\sqrt{\mu}} \ldots\ldots (18a)$$

(from Eqs. 9 and 14) where $T = [OH^-] + [HCO_3^-] + [CO_3^=]$ and $P = \tfrac{1}{2}[CO_3^=] + [OH^-] - [HCO_3^-]$ or $[HCO_3^-] = \tfrac{1}{3}T - 2P + [OH^-]$; and P, T, and $[OH^-]$ are expressed in parts per million as $CaCO_3$.

Free Carbon Dioxide

Free CO_2 is often confused with excess or "aggressive" CO_2. A certain amount of free CO_2 is necessary to maintain calcium carbonate in solution. The total free CO_2 minus the necessary free CO_2 as calculated from the saturation pH comprises the excess CO_2:

$$\text{ppm. excess } CO_2 = \frac{.88\,[\text{Alky.}]}{K'_1}\left([H^+] - \frac{K'_2\,[Ca^{++}][\text{Alky.}]}{K'_s \times 2 \times 10^9}\right) \ldots (19)$$

(from Eqs. 12 and 17) where $[Ca^{++}]$ and [Alky.] are expressed in parts per million (as Ca and $CaCO_3$ respectively).

Many data are presented in the literature on the removal of free CO_2 by aeration. To the authors' knowledge no successful effort has been made to correlate the amount of CO_2 removal with the efficiency of the iron precipitation. Very often it is apparent that considerably more

than the excess CO_2 is removed by vigorous aeration. The result is a shift of the equilibrium

$$Ca^{++} + 2HCO_3^- \rightarrow \underline{CaCO_3} + CO_2\uparrow + H_2O$$

to the right thereby supersaturating the water with or precipitating calcium carbonate. From the standpoint of corrosion prevention the disadvantage of introducing excessive dissolved oxygen may overcome the advantage of calcium carbonate supersaturation. This would be particularly true at dead ends of low circulation. From the standpoint of iron removal, precipitation of finely divided calcium carbonate may hinder rather than aid in the flocculation and settling of iron prior to filtration. This criticism is logical since a large excess of negatively charged calcium carbonate particles would tend to adsorb the positively charged ferric hydroxide particles (pH > 7.1) and remain in colloidal suspension. Since 1.0 ppm. ferrous iron requires only 0.14 ppm. oxygen for conversion to ferric hydroxide and since the original ferrous bicarbonate thereby releases only 1.6 ppm. CO_2, it is evident that many waters receive excessive aeration and would be more readily filtered if controlled aeration were practiced. This reasoning would be more applicable to waters of high alkalinity than to those of low alkalinity.

Saturation Index

The saturation pH may be calculated from Eq. 12 by converting $p[H^+]$ to pH and log $\frac{K_s'}{K_2'}$ to log $\frac{K_s}{K_2}$ and combining the corrections for salinity.

$$\mathrm{pH} = \log\frac{K_s}{K_2} - \log\,[\mathrm{Ca^{++}}] - \log\,[\mathrm{Alky.}] + 9.30 + \frac{2.5\sqrt{\mu}}{1 + 5.3\sqrt{\mu} + 5.5\mu} \quad \text{(12a)}$$

where $[Ca^{++}]$ and [Alky.] are expressed in parts per million (as Ca and $CaCO_3$, respectively).

Since the total free CO_2 calculation is limited in accuracy by the sensitivity of the pH determination, the saturation index, I, as calculated from Eq. 12a is used to denote the presence, (−), or lack, (+), of excess CO_2.

The saturation index may be calculated as follows:

$$I = \mathrm{pH} + \log\,[\mathrm{Ca^{++}}] + \log\,[\mathrm{Alky.}] - \log\frac{K_s}{K_2} - 9.30 - \frac{2.5\sqrt{\mu}}{1 + 5.3\sqrt{\mu} + 5.5\mu} \quad \text{(12b)}$$

where pH is the actual pH measured experimentally.

Although the presence of sulfates increases the ionic strength, μ, 1.46 times the increase produced by chlorides in similar concentration (in

ppm.), it is significant that high sulfate waters are generally also of high calcium concentration, whereas high chloride waters generally are accompanied by a high sodium concentration. The calcium content offsets the corrosive tendencies as indicated by the increase in μ by the addition of salts. Therefore, the high chloride waters are more notorious for their corrosive action than high sulfate waters.

It is advisable to measure pH at the temperature at which the equation is to be applied, and to choose the constants for this temperature. Increasing the temperature tends to precipitate $CaCO_3$ and yield a false pH. Theoretically a state of + saturation should not exist. Its existence is due to a condition of incomplete reaction, a condition which is more likely to prevail at relatively low calcium and carbonate ion concentrations. Since pH varies directly as pK_1, however, the saturation index at any temperature should vary from that at 25° by the difference between $p\frac{K_1K_s}{K_2}$ at that temperature and $p\frac{K_1K_s}{K_2}$ at 25°C. The variation amounts to .015 unit per degree (Table 2).

TABLE 2

Variation of Saturation Index With Temperature

Temp. °C.	0	10	20	30	40	50	60	70	80
$K_1K_s/K_2 \times 10^5$	10.5	7.28	5.07	3.55	2.46	1.78	1.29*	.92*	.68*
$p(K_1K_s/K_2)$	3.98	4.14	4.29	4.45	4.61	4.75	4.89*	5.04*	5.17*

* Extrapolated.

Summary

A correlating discussion has been given on the different forms of alkalinity and their relation to free and excess CO_2 and the saturation index. The activity concept has been extended to produce more nearly correct results for calculations for waters of greater than 500 ppm. mineral content.

More recent and corrected data for the fundamental constants involved have been indicated and the correct variation of the solubility product of calcium carbonate with temperature has been calculated. A method has been included for calculation of pH from phenolphthalein and methyl orange alkalinity determinations. The relation between "aggressive" CO_2 and the saturation index is indicated.

The authors wish to acknowledge the comments of Dr. John Johnston and Dr. D. A. MacInnes, who confirmed the authors' opinions concerning the misinterpretation of their respective data (4, 7).

References

1. Tillmans, J. and Heublein, O. Investigation of the Carbon Dioxide Which Attacks Calcium Carbonate in Natural Waters. Gesundh. Ing. (Ger.), **35:** 669 (1912).
2. Greenfield, R. E. and Baker, G. C. Relationship of Hydrogen-Ion Concentration of Natural Waters to Carbon Dioxide Content. Ind. Eng. Chem., **12:** 989 (1920).
3. Johnston, J. and Frear, G. L. The Solubility of Calcium Carbonate (Calcite) in Certain Aqueous Solutions at 25°. J. Am. Chem. Soc., **51:** 2082 (1929).
4. Johnston, J. and Williamson, E. D. The Complete Solubility Curve of Calcium Carbonate. J. Am. Chem. Soc., **38:** 975 (1916).
5. Langelier, W. F. The Analytical Control of Anti-Corrosion Water Treatment. Jour. A.W.W.A., **28:** 1500 (1936).
6. Strohecker, R. A New Way to Ascertain the Aggressiveness of Waters. Z. fur Anal. Chemie (Ger.), **107:** Nos. 9, 10 (1936).
7. MacInnes, D. A. and Belcher, D. The Thermodynamic Ionization Constants of Carbonic Acid. J. Am. Chem. Soc., **55:** 2630 (1933).
8. Moore, E. W. Graphic Determination of Carbon Dioxide and the Three Forms of Alkalinity. Jour. A.W.W.A., **31:** 51 (1939).
9. Harned, H. S. and Hammer, W. J. The Ionization Constant of Water and the Dissociation of Water in Potassium Chloride Solutions From Electromotive Forces of Cells Without Liquid Junction. J. Am. Chem. Soc., **55:** 2194 (1933).
10. Shedlovsky, T. and MacInnes, D. A. The First Ionization Constant of Carbonic Acid, 0 to 38°, From Conductance Measurements. J. Am. Chem. Soc., **57:** 1705 (1935).
11. Harned, H. S. and Cook, M. A. The Ionic Activity Coefficient Product and Ionization of Water in Uni-Univalent Halide Solutions—A Numerical Summary. J. Am. Chem. Soc., **59:** 2304 (1937).
12. Langelier, W. F. *Discussion*—Practical Application of the Langelier Method (Charles P. Hoover). Jour. A.W.W.A., **30:** 1806 (1938).
13. Harned, H. S. and Sholes, S. R. The Ionization Constant of HCO_3^- From 0 to 50°. J. Am. Chem. Soc., **63:** 1706 (1941).
14. Shedlovsky, T. and MacInnes, D. A. The Determination of Activity Coefficients From the Potentials of Concentration Cells With Transference. III. Potassium Chloride. IV. Calcium Chloride. J. Am. Chem. Soc., **59:** 503 (1937).
15. Bohr, C. Determination of Invasion and Evasion Coefficients in the Solution of Gases in Liquids—Carbonic Anhydride in Water and Aqueous Salt Solutious. Ann. Physik und Chemie (Ger.), **68:** 500 (1899).
16. Walker, A. C., Bray, U. B. and Johnston, J. Equilibrium in Solutions of Alkali Carbonates. J. Am. Chem. Soc., **49:** 1235 (1927).
17. *Standard Methods for the Examination of Water and Sewage.* Am. Pub. Health Assn. and Am. Water Works Assn., New York (8th ed., 1936).
18. MacInnes, D. A. and Belcher, D. The Thermodynamic Ionization Constants of Carbonic Acid at 38° From Electromotive Force Measurements. J. Am. Chem. Soc., **57:** 1683 (1935).
19. DeMartini, F. E. Corrosion and the Langelier Calcium Carbonate Saturation Index. Jour. A.W.W.A., **30:** 85 (1938).

Discussion by *Harvey F. Ludwig*.* The Langelier equation may be most simply expressed in the form:

$$pH_s = K + pCa + pAlky.$$

in which K is a constant depending upon temperature and upon ionic strength or, roughly, total solids or "salinity." In order to use this equation, the value of K must be determined, and in his original paper Professor Langelier provides means for such determination for a wide range of temperatures and for total solids up to a maximum of about 800 ppm. Larson and Buswell in their discussion have simply compiled pertinent correction equations published in the literature of physical chemistry which are intended for use to: (1) determine K for any temperature (salinity constant) more accurately than by the method given by Langelier; and (2) determine K for any salinity (temperature constant) beyond 800 ppm. total solids. Larson and Buswell offer no laboratory data to test the applicability of these correction equations, nor do they state any opinion by themselves or others as to how reliably these correction equations might be generally applied.

In limited thesis research studies on various waters of high salinity, conducted in 1938 at the University of California by Walfred Flod and the writer, the value of K for these waters was both determined experimentally in the laboratory and computed from the correction equations published in the physical chemistry literature. The agreement between the experimental and computed values was not good. Consultation was had with several physical chemists, who confirmed the belief that the published correction equations are too limited in scope and inadequately developed for reliable general application.

Professor Langelier's original work does contain limitations, but, in the opinion of the writer, he has clearly stated these as such and it is probable that he has developed the theory as well as can be done in the absence of further laboratory data.

Discussion by *W. F. Langelier*.† In the foregoing paper by Larson and Buswell, the authors accept without question the basic theory of the writers' equation (Eq. 12) for computing the pH at which a given water is in equilibrium or just saturated with calcium carbonate. This equation contains two experimental constants pK'_2 and pK'_s. The values of these constants, together with their temperature and salinity corrections, are criticized as not being sufficiently precise. Perhaps the strongest criticism relates to the error involved in neglecting to consider the hydrolysis effects in the

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temperature correction of pK'_s. In order to show the magnitude of error involved in the writers' simplified treatment, the values of pK'_s obtained by both methods are given in Table 3. It will be noted that only at the extreme temperatures are the errors as great as 0.2 units of equivalent pH in the computed Index.

TABLE 3

Comparative Values of pK'_s at Zero Ionic Strengths for Various Temperatures by Two Methods

Temperature, °C.	0	10	20	25	30	40	50	60	70	80
pK'_s (Langelier)*	7.81	8.03	8.24	8.32	8.40	8.58	8.74	8.90	9.03	9.18
pK'_s (Larson and Buswell)†	8.02	8.15	8.28	8.34	8.39	8.51	8.62	8.74	8.86	8.97
Difference	−0.21	−0.12	−0.04	−0.02	+0.01	+0.07	+0.12	+0.12	+0.17	+0.21

* $pK'_s = 8.32 - 2\left(\frac{830}{T_{abs.}} - 2.78\right)$.

† Neg. log of K_2 values given in Table 1.

TABLE 4

Comparative Values of pK'_s for Various Ionic Strengths (Salinity) by Two Methods at 25°C.

Ionic Strength (μ)	0.000	0.005	0.010	0.015	0.020
Approx. Total Solids, ppm.	0	200	400	600	800
pK'_s (Langelier)*	8.32	8.04	7.92	7.83	7.76
pK'_s (Larson and Buswell)†	8.34	8.12	8.05	8.01	7.98
Difference	−0.02	−0.08	−0.13	−0.18	−0.22

* $pK'_s = 8.32 - 4\sqrt{\mu}$

† $pK'_s = 8.34 - \frac{4\sqrt{\mu}}{1 + 3.9\sqrt{\mu}}$

Similarly in the salinity corrections applied to pK'_s, a comparison of the values obtained by the two methods (Table 4) indicates only minor discrepancies when applied to normal waters of moderate salinity.

It is not possible to make similar direct comparisons between the results obtained by the two methods for estimating the temperature corrections for pK'_2, due to the fact that, in the writers' simplified treatment, provision

is made to determine pH after the samples are brought to room temperature of 25°C. The error thus introduced, it was assumed, would just neutralize the temperature correction applicable to the 25°C. value of pK'_2. Correction was made, however, for salinity effects and a comparison of the values with those of Larson and Buswell are given in Table 5, which shows that the differences are small and again are within the errors of routine pH measurement.

In Table 6 the values of pK'_2 and pK'_s at 25°C. for various temperatures are given. These are the values which were furnished to C. P. Hoover for the preparation of his nomograph (Jour. A.W.W.A., **30:** 1802 (1938)).

The more rigorous treatment of ionic strength and hydrolysis corrections reported by Larson and Buswell seems to the writer hardly warranted in view of the fact that the ionic strength and activity product theories have by no means proved to be of precise quantitative application. The subject of ionic strength corrections was extensively studied by students in the writer's laboratory in 1938 and proposed equations were found to have

TABLE 5

Comparative Values of pK'_2 for Various Ionic Strengths at 25°C.

Ionic Strength (μ)	0.000	0.005	0.010	0.015	0.020
pK'_2 (Langelier)	10.26	10.24	10.22	10.20	10.18
pK'_2 (Larson and Buswell)	10.33	10.20	10.16	10.13	10.10
Difference	−0.07	+0.04	+0.06	+0.07	+0.08

qualitative but not quantitative application, especially in the higher ranges of salinity. Anticipating this probability, the writer originally resorted to the use of an "index number" indicative merely of "directional tendency and driving force." For practical use, it is now believed that the term $(pK'_2 - pK'_s)$ should be obtained empirically by experiment with a few typical waters of varying salinities and temperatures, and it is proposed to carry out such a study in the near future. This study may prove that the original generalizations have limited applications, but certainly the published evidence to date indicates a fair correlation between theory and practice when applied to normal fresh waters of moderate salinity.

The writer feels it necessary to caution against a too liberal interpretation of the saturation index theory as applied to miscellaneous technological problems in water chemistry. Thus, in pipe corrosion, which only in certain instances is manifested by so-called red water troubles, it is necessary to consider additional environmental factors. The normal film-forming materials are hydrated iron oxide and calcium carbonate,

each of which is produced in a colloidal condition. Whether these coagulate and become attached to the pipe wall or disperse in the flowing water may well depend upon the relative concentrations of ions which are not involved in the carbonate equilibrium. Also to be considered are mechani-

TABLE 6

Values of pK'_2 and pK'_s at 25°C. for Various Ionic Strengths and of the Difference ($pK'_2 - pK'_s$) for Various Temperatures

Ionic Strength	Total Dissolved Solids	25°C.			($pK'_2 - pK'_s$)									
		pK'_2	pK'_s	$pK'_2 - pK'_s$	0°C.	10°C.	20°C.	30°C.	40°C.	50°C.	60°C.	70°C.	80°C.	90°C.
	ppm.													
0.0000		10.26	8.32	1.94	2.45	2.23	2.02	1.86	1.68	1.52	1.36	1.23	1.08	0.95
0.0005	20	10.26	8.23	2.03	2.54	2.32	2.11	1.95	1.77	1.61	1.45	1.32	1.17	1.04
0.001	40	10.26	8.19	2.07	2.58	2.36	2.15	1.99	1.81	1.65	1.49	1.36	1.21	1.08
0.002	80	10.25	8.14	2.11	2.62	2.40	2.19	2.03	1.85	1.69	1.53	1.40	1.25	1.12
0.003	120	10.25	8.10	2.15	2.66	2.44	2.23	2.07	1.89	1.73	1.57	1.44	1.29	1.16
0.004	160	10.24	8.07	2.17	2.68	2.46	2.25	2.09	1.91	1.75	1.59	1.46	1.31	1.18
0.005	200	10.24	8.04	2.20	2.71	2.49	2.28	2.12	1.94	1.78	1.62	1.49	1.34	1.21
0.006	240	10.24	8.01	2.23	2.74	2.52	2.31	2.15	1.97	1.81	1.65	1.52	1.37	1.24
0.007	280	10.23	7.98	2.25	2.76	2.54	2.33	2.17	1.99	1.83	1.67	1.54	1.39	1.26
0.008	320	10.23	7.96	2.27	2.78	2.56	2.35	2.19	2.01	1.85	1.69	1.56	1.41	1.28
0.009	360	10.22	7.94	2.28	2.79	2.57	2.36	2.20	2.02	1.86	1.70	1.57	1.42	1.29
0.010	400	10.22	7.92	2.30	2.81	2.59	2.38	2.22	2.04	1.88	1.72	1.59	1.44	1.31
0.011	440	10.22	7.90	2.32	2.83	2.61	2.40	2.24	2.06	1.90	1.74	1.61	1.46	1.33
0.012	480	10.21	7.88	2.33	2.84	2.62	2.41	2.25	2.07	1.91	1.75	1.62	1.47	1.34
0.013	520	10.21	7.86	2.35	2.86	2.64	2.43	2.27	2.09	1.93	1.77	1.64	1.49	1.36
0.014	560	10.20	7.85	2.36	2.87	2.65	2.44	2.28	2.10	1.94	1.78	1.65	1.50	1.37
0.015	600	10.20	7.83	2.37	2.88	2.66	2.45	2.29	2.11	1.95	1.79	1.66	1.51	1.38
0.016	640	10.20	7.81	2.39	2.90	2.68	2.47	2.31	2.13	1.97	1.81	1.68	1.53	1.40
0.017	680	10.19	7.80	2.40	2.91	2.69	2.48	2.32	2.14	1.98	1.82	1.69	1.54	1.41
0.018	720	10.19	7.78	2.41	2.92	2.70	2.49	2.33	2.15	1.99	1.83	1.70	1.55	1.42
0.019	760	10.18	7.77	2.41	2.92	2.70	2.49	2.33	2.15	1.99	1.83	1.70	1.55	1.42
0.020	800	10.18	7.76	2.42	2.93	2.71	2.50	2.34	2.16	2.00	1.84	1.71	1.56	1.43

cal or physical effects, as for example the release of air bubbles through temperature rise at the metal surface, which could well disturb protective film attachment and induce corrosion through the formation of cathode areas. These facts, however, do not invalidate the saturation theory if its limitations are properly considered.

Authors' Closure: Professor Langelier indicates clearly in his tables the differences due to the use of the revised constants. These differences are cumulative in the case of pK'_2 and pK'_s and, if the temperature is less than 25°C., the numerical difference is again cumulative. From his Tables 4 and 5, it can be seen that, for a water of 800 ppm. mineral content, $pK'_2 - pK'_s$ at 25°C., the use of the newer constants on the literature leads to a net difference of +0.30. At 10°C. the difference in pK'_s indicates an additional 0.12 difference. This makes the net error*, in this not unlikely case, +.42, which exceeds the error of even a crude determination of pH. This may not be significant in some applications of the equation, but for individuals or committees who are attempting to correlate corrosion and red water data on more than one particular supply, such corrections cannot help but be of aid.

If saturation index data of no better than ±0.10 accuracy are satisfactory, there should be no necessity for including calculations involving activity. The last term in Eq. 12b involves overall correction for salinity of only 0.1 to 0.2 (at 100–1000 ppm. residue) to be substracted from the index value obtained from pH, Ca^{++}, Alky., K_s and K_2 without involving the ionic strength concept.

In this connection, Fig. 2 indicates the overall correction for salinity and the plot of log K_s/K_2 simplifies calculation of the saturation index by Eq. 12b.

There is no question of acceptance of the basic theory of Eq. 12. This theory has been long established, prior to conception of the term pH and back into the last century. However, Tillmans must receive credit for initial application in the water works field. Also, Professor Langelier must be cited for the presentation of this theory in a readily useable form.

It appears peculiarly inconsistent to the authors that Professor Langelier presents his Table 6 in which $(pK'_2 - pK'_s)$ values are presented to the second decimal place, 0.01 unit, after indicating by his Tables 3, 4 and 5 that these figures are inconsistent by several tenths of a unit with more recently accepted values for the constants involved, and in view of the fact that routine pH measurement is not considered by him to be accurate to ±0.08 pH unit.

It is the authors' suggestion that all reliable data on $CaCO_3$ saturated solutions be plotted in the following manner. "I" *vs* "mineral content" or $\sqrt{\text{mineral content} \times 0.000025}$, where I = pH + log [Ca^{++}] + log

* Editor's Note: Professor Langelier has registered an objection to this term, suggesting that "possible discrepancy by the two methods" would be more accurate. The authors, however, indicate that their sources of information, as given in the reference list, give no basis for considering the deviation "anything but 'net error' until proved otherwise."

[Alky.] $-$ log $\frac{K_s}{K_2}$ $-$ 9.30. [Ca^{++}] and [Alky.] are in ppm. as Ca and $CaCO_3$ respectively. It is to be noted that an appreciable error is induced if log K_s/K_2 is not taken for the same temperature as that on which the pH was determined. Such data will indicate the extent to which the salinity factor is reliable.

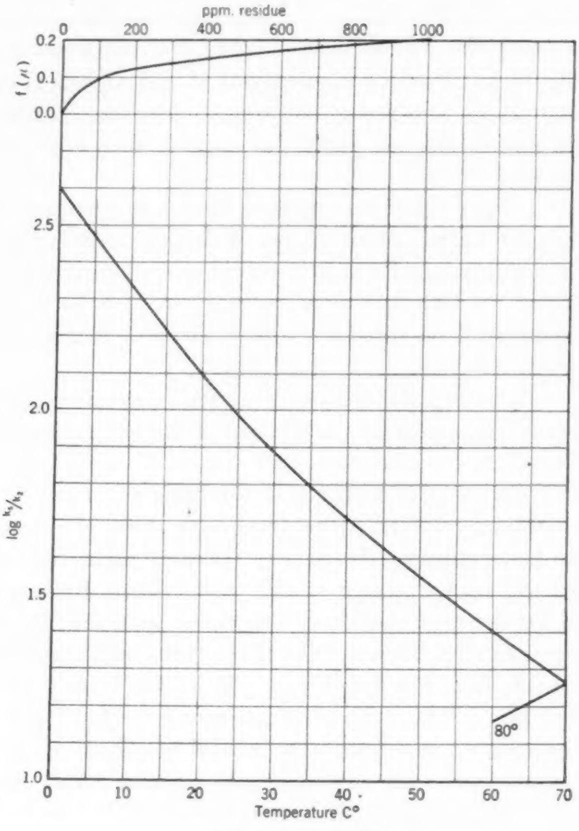

FIG. 2. Log K_s/K_2

The authors are in complete accord with Professor Langelier's warning against "too liberal interpretation of the saturation index theory" and regard the contribution as only a step in the direction of learning how far the theory can stand by itself without explaining discrepancies to an unknown or several of many environmental factors.

Health Departments in Wartime

By A. H. Stewart

THE program of the Pennsylvania Department of Health has been profoundly affected by the war. Other state health departments, undoubtedly, are also confronting the problems that have accompanied the all-out effort of the American people to win this struggle for the survival of freedom. Problems of venereal disease control, of environmental sanitation, of transiency and of housing are only a few of the new and perplexing tasks that are of direct concern to both public health workers and the medical profession. To perform them adequately has necessitated a shift in the normal programs of health departments.

The loss of nearly 200 employees of the Pennsylvania Department of Health to the armed forces within the past year has further added to its burden. These employees included physicians, nurses, dentists, engineers, statisticians and other specialists in the public health field. Replacements have been virtually impossible to obtain in most cases, but with its sails trimmed to fit the wind the department is carrying on its work of safeguarding the state's human resources from disease in many spheres.

With the mobilization of the National Guard in January 1941, a special unit of trained sanitarians under the direction of an epidemiologist was organized to carry on intensive work in the control of communicable disease and in general sanitation in the area within a 25-mile radius of Indiantown Gap. Work of this type has since been extended to the zones about various military installations.

Protective measures to insure the purity of public water supplies became the responsibility of the department's Bureau of Sanitary Engineering. This bureau has a personnel of some sixty men and women, comprising sanitary, civil and chemical engineers, chemists, industrial waste experts and the requisite stenographic and clerical aides.

The bureau engineers have been co-operating with water works officials and with the Office of Civilian Defense, both federal and state, to the end that adequate protection may be provided against sabotage and against

A paper presented on September 18, 1942, at the Western Pennsylvania Section Meeting, Pittsburgh, by A. H. Stewart, Secy., Pennsylvania Department of Health, Harrisburg, Pa.

the emergencies occasioned by air raids. The measures adopted are in general based upon the experience of water works abroad where such emergencies have actually taken place.

Industrial Water Supply Problems

Another phase of this problem is that occasioned by the increased demand for public water supply by the expanded industries of the state, largely caused by war production activity. Such demands have taxed the facilities of many plants, requiring increased vigilance to assure a satisfactory output both in quantity and quality, so that there may be no interference with the production of materials and equipment so essential to war uses.

An important feature of this work is the supply of water for Army camps and the various types of military depots located within the state. There, the first problem is to furnish a satisfactory water supply for the thousands of workmen engaged in the construction of such plants and later for the permanent forces stationed there. Frequently these problems involve securing additional or auxiliary supplies.

As a result of this increased industrial activity, there is also a corresponding increase in industrial wastes to be cared for properly if the state's streams are to be protected. New problems are presented in the case of industries, many of vast extent, which must be supplied with immense volumes of water and whose wastes are unusually damaging to the streams receiving them.

As examples, mention may be made of two extremely large powder manufacturing plants now under construction, where the daily use of water far exceeds that of the state's large cities. As all of these are rush jobs, immediate attention must be given to their problems so that no hindrance may be placed in the strenuous efforts to bring these plants to early production.

The Sanitary Water Board, for which the Department of Health is the agent, is fully aware of the hazards to Pennsylvania's waters, resulting from the accelerated activity along this line. A campaign for the protection of state waters has been started by the board with the issuance of sweeping orders to industries and municipalities on the various watersheds, requiring that suitable steps be taken to provide protection for these streams. Among other things involved is the matter of discharge of culm into the Schuylkill River in the anthracite region, where an intensive study is now being undertaken by the mining industry and the department in an attempt to solve a particularly vexatious problem.

Trailer camps and cabin camps for industrial workers are the result of inadequate housing facilities; and with them have arisen the sanitary

problems of location, adequate water supply, disposal of wastes and prevention of nuisances. It is an established policy of the Department of Health to supervise all cabin and trailer camps, whether tourist or defense, and to protect them against those diseases which result from unsafe water supplies, and insanitary methods of waste disposal.

Control of Venereal Disease and Immunization

In another field, there has been active co-operation by the department with the military authorities in investigating reported sources of venereal infections and placing them under treatment and, when necessary, under quarantine. A continuous prophylaxis service has been made available to members of the armed forces in Philadelphia. The municipal departments of health without exception have actively co-operated with the state department in the matter of investigating sources of venereal infections reported by the armed forces.

Laboratories of the Department of Health, private laboratories and those of the Philadelphia and Pittsburgh Health Departments performed 480,035 serologic blood tests for syphilis on Selective Service registrants up to June 30, 1942.

Selective Service registrants rejected from the Army because of active tuberculosis are also referred to the department's field nurses for investigation. Those financially unable to bear the cost are offered treatment by the state, which maintains 90 tuberculosis clinics, 30 pneumo-thorax, or chest surgery, centers and 3 sanatoriums.

Advantage has been taken of all the proved advances in immunization against infectious diseases. In addition to the serums and antitoxins heretofore distributed by the Department, new types have been made available, including: gas gangrene antitoxin and tetanus antitoxin in treatment-sized doses, gas gangrene and tetanus antitoxins combined for use in preventing these diseases; immune globulin for the prevention of measles; Rocky Mountain Spotted Fever vaccine for the prevention of that disease, combined diphtheria and tetanus toxoids for permanent protection against these diseases; and pneumonia serums for each of the known 34 types of pneumococcus pneumonia.

Industrial Hygiene and Health Education

In modern warfare armies without supplies cannot endure. A huge army of producers must work ceaselessly to insure an ever-increasing flow of these vital materials. The Pennsylvania Division of Industrial Hygiene has been concentrating its activities on protecting the health of the war workers in the state. Its staff of physicians, engineers, chemists and other technical personnel furnishes medical and engineering services to Pennsyl-

vania industrial plants. The division maintains a central laboratory in Harrisburg and branch laboratories and offices in Philadelphia, Pittsburgh, Erie, Altoona, Williamsport and Scranton. Medical services offered free to Pennsylvania industries include: consultation on the diagnosis and prevention of occupational diseases; assistance and advice in the organization of adequate medical programs in industrial plants; and studies of occupational diseases and other conditions affecting the health of industrial groups. Posters and literature on the control and prevention of venereal disease were distributed to more than 1,500 plants last year.

It is estimated by conservative industrial hygiene experts that if the country were this year to reduce by only 10 per cent the number of man-hours lost last year through the sickness of workers in industry, it would have extra labor available to build five battleships or 16,047 combat tanks. With industry on a three-shift day these totals are multiplied.

The Division of Health Education of the Department of Health has stepped up its activities over an extended front to meet the demands of the war program. Groups long in need of enlightenment on disease prevention and how to improve their health are being reached by this division's statewide campaign. Visual-aid instruction, through the medium of motion pictures and sound films, is employed in teaching hygienic principles and practices to the public. A library of 150 film prints has been assembled. Each title is in constant demand and no charge is made either for the film or for the equipment necessary to show it. Field workers, representing this division in twenty districts of the state, also assist community leaders in organizing health activities.

These are the major effects of the war on the activities of the Pennsylvania Department of Health. To win the war will require the all-out effort of everyone. It must naturally follow, therefore, that good health for all the people is essential to an effective total defense and to the creation of an unbeatable war machine. The promotion of that objective is the responsibility and guiding function of the state departments of health.

Pumping Stations in the Blitz

By Henry Berry

BRITAIN'S water undertakings know that, come what may, the supply of water to the populations of cities, great and small, must go on. Never was this high sense of duty better exemplified than during the long drawn out nightly raids on London in the fall of 1940 and the early days of 1941. In spite of all the efforts of the Nazis, pumping went on and London had its water—water, moreover, of the usual high quality. It was a case of "hats off" to everyone concerned and especially to the pumping station staffs.

Every drop of the approximately 300 mgd. supplied to the 6½ to 7 million consumers in "Water London" must be pumped. Unlike some cities, with a gravity supply, London gets its water from the Rivers Thames and Lee, and from wells sunk in the deep chalk formations. To reach its destinations at the various heights of the Greater London area, some of this water must be re-pumped two or three times; so the pumps *must* continue to work.

Naturally, at every pumping station, air raid shelters were provided for such of the staff as could be spared during raids, but boilers cannot be fired from the shelters, nor can engines and pumps be run, so those responsible had to stay at their posts no matter what happened outside—and stay they did.

Prior to the raids, arrangements had been made for protecting the vital parts of engines and pumps from flying splinters, bursting bombs and, in fact, everything except a direct hit, from which there could be no protection. Some of the protection for the engines was useful also for the staff, but a certain amount of risk was always present.

Seventh in a series of articles entitled "Water Service in Wartime," prepared by Henry Berry, Chairman of the Metropolitan Water Board of London, England, as a comprehensive study of wartime water works problems in the London metropolitan area. The previous six articles of the series were published in the September 1942 JOURNAL.

Wartime Work Shift System

In peacetime the Metropolitan Water Board's pumping station staffs run on a three-shift system which, with the reliefs provided, permits a 48-hour work week. For obvious reasons exact details of wartime alterations to this system or facts about the times of the change-over of the shifts cannot be given, but it can be said that every shift turned up at the appropriate time and took over from the outgoing workers, no matter what the difficulties or dangers.

There were, of course, occasions when the incoming shift was delayed because of the difficulties of transport, when streets were blocked with bomb craters or demolished buildings and when subways were held up because of damage. Whenever this occurred, the outgoing shift, either wholly or in its appropriate parts, remained at its posts until it was relieved. Arrangements were made in preparation for housing and billeting workers, but it was not found necessary to put them into force.

The work of running the plant was by no means normal, for broken mains due to bomb action resulted in sudden drops in pressure, and engines had either to be shut down or throttled to prevent racing. Again, careful adjustments had to be made to keep the various loads balanced.

Nervous Strain on Personnel

A further handicap from which pumping station staffs suffered was that, while they were in their stations attending to their duties, they had little knowledge of what was going on outside, for even the noise of exploding bombs and anti-aircraft fire was deadened in the enclosed space by the noise of the plant. Most of these workers had wives and children and suffered acutely from lack of knowledge of what was happening to their families; but they remained steadily at their posts and kept London supplied with water.

Conditions in pumping stations, blacked-out and totally enclosed, were anything but pleasant. The temperature was considerably higher than in normal conditions, despite all attempts at extra ventilation the effectiveness of which was lessened by the necessity of safeguarding against the possibility of gas attack.

Use of Mobile Plant

When it was necessary, for one cause or another, to shut down stations wholly or partially, other stations, hitherto kept either as standbys or regarded as superfluous, had to be put into commision.

Arrangements had been made whereby mobile plant could be attached to specially made connections in the event that stations were put out of action. The connections were some distance from the pumphouse but the

mobile plant could deal effectively with the bulk of the station load. In only one case was it necessary to use such mobile plant, despite pre-blitz forebodings. On that occasion it was possible to start up the mobile plant in a very short period—hours rather than days—and to carry on with the station's load.

The mobile plant was of various descriptions: steam-driven with mobile boilers, electric-driven from current derived from diesel electric sets, etc. The pumping sets were arranged so that no matter what the prime mover, the sets could be accommodated to their work.

Prior to the blitz all the mobile plant and the various connections at each of the key stations had been thoroughly tested under running conditions so that, when the blow fell, everything was in order.

Experience During Raids

The names of stations cannot, of course, be given, but some interesting instances are worthy of note. On the occasion of the explosion of a very heavy bomb at one key works, all the windows were blown out and glass was scattered all over the engine and boiler rooms, but the staff showed the utmost coolness. Every light possible was extinguished, and the closet watch was kept on all moving parts of the engines to ensure that no hot bearings developed as a result of the glass, grit and dust everywhere.

One night, large mains in the west end of London were hit and in consequence another station in the northwest had to be started. A man was sent to these works, normally shut down, to get things started. Just as he arrived, a large bomb burst a short distance away, knocking him off his bicycle and partially stunning him. He picked himself up, however, and went on to the station, and soon was able to report that the whole plant was ready for pumping.

In the past it was said that no man was a good engineer unless he could improvise. In these days of mass production and chain-line feeds, the genius for improvisation has not entirely disappeared, as was shown in one case where the high-pressure water supply for charging pumps failed when the station was required to start. By exercising considerable ingenuity in the use of fire hoses and the manipulation of valves, the foreman in charge succeeded in starting the plant, using low-pressure water, with only 20 ft. head instead of the normal 120 ft.

The men concerned in these and many other episodes received no public recognition or decoration, but they all had the inward satisfaction of knowing that they did their job magnificently and that London's millions had their water.

ABSTRACTS OF WATER WORKS LITERATURE

Key: 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

WARTIME WATER WORKS PROBLEMS

Bacterial Warfare. Leon A. Fox. Mil. Surgeon **90:** 563 (May '42). Use of communicable disease organisms as warfare instrument considered by Conf. on Limitation of Armaments in '22. Int. committee appointed then, reported later as follows: Bact. injury effects not limited or localized. Modern water purif. methods protect against typhoid and cholera organisms. Plague is disease as dangerous for force using organisms as for those attacked. Danger from typhus exaggerated. Modern methods effective in controlling communicable diseases. With bact. warfare, author also considers filterable viruses, protozoa, other pathogenic forms and their toxic products, thus referring collectively to biologic warfare. Communicable diseases constituting epidemic or pandemic threat to military forces are: intestinal, respiratory and insect-transmitted. Although terrible epidemics of typhoid, cholera, dysentery and diarrheal conditions destroyed military forces in past, reoccurrence highly questionable, because, their epidemiology being so thoroughly understood, modern san. methods and immunization processes render them comparatively innocuous. Possibility of contamg. milk supply offers practically insurmountable difficulties, although theoretically possible spies might thus discommode and harass civil pops. No practical application to military forces themselves. Contamn. of water supplies in civilian communities by infecting large reservoirs and storage basins possible. To be effective, however, contamn. necessarily subsequent to filtration and chlorination treatment by modern water purif. plant still possible. Reason modern armies and civilized communities without serious epidemics from intestinal group because modern san. protects personnel, not because infective agents absent. Incidence of typhoid and cholera carriers cited to prove point. Effectiveness of respiratory diseases, influenza, pneumonia, diphtheria, epidemic meningitis, depends not upon danger of introducing infective agent but upon creation of epidemic conditions—soil in which organism could produce epidemic—as overcrowding and lessened resistance. Potentially as hazardous to force using such infective agents as to foe. Difficulty of starting epidemics of insect-transmitted diseases, malaria, dengue, yellow fever, typhus and sleeping sickness renders them unsuited for war purposes. Their epidemiology understood and controllable. Same may be said for rodent-borne bubonic plague. Soldier's greatest danger from venereal diseases. Infective disease processes, including infections of tetanus, gas gangrene, anthrax and ordinary pus formers, mentioned by some as possible war weapons. Author dismisses these as impractical because, for them to be dangerous, must be kept alive. Problem

of effective dissemination unsolved. Even if successful, effectiveness too local to be of value. Bact. contamn. not impossible, but use of living organisms in offensive warfare presents technical difficulties not generally considered. Same reasoning applies to use of toxic products, e.g., botulinus toxin. Highly questionable if biologic agents suited for warfare. —*Ralph E. Noble.*

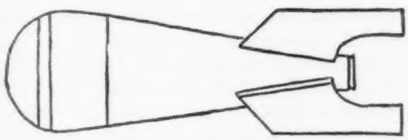

Fig. 1

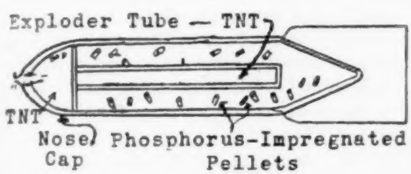

Fig. 2

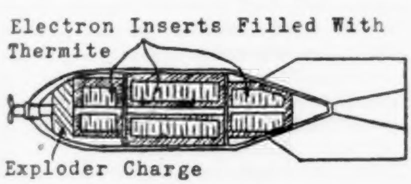

Fig. 3

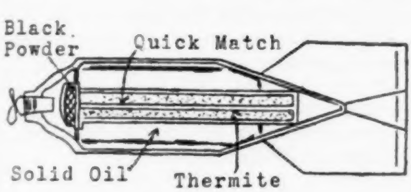

Fig. 4

Japanese Incendiary Bombs. ANON. Natl. Fire Prot. Assn. News Letter, No. 303: 3 (Sept. '42). U.S. Army Chem. Warfare Service advises that following incendiary bombs known to have been used by Japanese in present campaigns. Information from summary issued by Portland, Ore., Defense Council.

1-KG. (2.2-LB.) INCENDIARY BOMB (FIG. 1): *Specifications:* Overall length, 10.2″; body length, 9.05″; diam. of body, 3.0″; tail length, 4.3″; diam. of tail, 3.1″. *Markings:* Body painted black; tail painted white; red 4 inside case; no. 6503 on striker head. *Filler:* Red phosphorus in tail portion with exploder tube filled with picric acid. *Operation:* Bomb serves dual purpose of incendiary and anti-personnel bomb. Hemispherical rubber-nose cap with mushroom-shaped striker inside. When bomb lands striker pierces detonator which initiates picric acid in exploder tube. Exploder tube, in turn, fires red phosphorus and at same time explodes bomb into small fragments which have shrapnel effect up to approx. 50 yd.

50-KG. (110-LB.) PHOSPHORUS PELLET BOMB (FIG. 2): *Specifications:* Overall length, 40″; body length, 33.0″; diam. of body, 7.0″; tail length, 15.0″; diam. of tail, 9.0″. *Markings:* Painted blue-gray; 1″ white band near center; red band behind fuse. *Filler:* Cylindrical black rubber pellets, $1\frac{1}{16}''$ long by 1″ in diam., surrounding central exploder tube. Pellets impregnated with phosphorus, and bomb case filled with liquid, preventing ignition of phosphorus. *Operation:* When bomb falls, fuse ignites exploder tube charge which ruptures case, scattering pellets to distances of as much as 50 yd. When pellets dry out, phosphorus ignites rubber, causing small fires which burn 5 to 7 min. with flame 4″ to 6″ high and gray smoke with odor of burning rubber.

60-KG. (132-LB.) THERMITE INCENDIARY BOMB (FIG. 3): *Specifications:* Overall length, 39.8″; body length, 28.2″; diam. of body, 7.8″; tail length, 18.2″; diam. of tail, 9.7″. *Markings:* Blue-gray; tips of tail vanes painted red. *Filler:* 3 magnesium alloy "fire pots" within body. One in the cone of tail; other two are in main body. Each filled with thermite which, when ignited, melts and ignites magnesium case of "fire pot." Also starter pot which, when ignited by fuse, serves to ignite "fire pot" thermite filling. *Operation:* When bomb falls, fuse ignites propelling charge which ejects "fire pots." At same time, fuse ignites starter pot which in turn fires

"fire pots." Burning "fire pots" scattered when ejected from bomb case and act as separate thermite incendiary bombs, thus increasing radius of damage. In some cases, bomb fails to act properly and penetrates ground before "fire pots" ejected. In such instances, "fire pots" found in or near hole of entry. Usually indicated by considerable volume of gray smoke issuing from hole in ground. Ground powder of burned thermite also found in hole of entry.

60-KG. (132-LB.) SOLID OIL INCENDIARY BOMB (FIG. 4): *Specifications:* Overall length, 41.6"; body length, 25.3"; diam. of body, 9.5"; tail length, 16.4"; diam. of tail, 13.2". *Markings:* Blue-gray; tips of all vanes painted red. *Filler:* Solidified, inflammable oil surrounding central ignition and exploder tube of thermite. Propelling charge located in nose ignited by nose fuse. *Operation:* When bomb falls, fuse ignites exploder charge which ejects inner case contg. the oil. At same time, fuse ignites thermite in exploder tube. Thermite in turn melts and ignites oil scattered. If these bombs found unexploded, they are in highly sensitive condition. No attempt should be made to move them but they should be reported in same way as any other unexploded bomb.—*Ed.*

Wartime Scientific Manpower Production. JOHN S. NICHOLAS. Science. **96:** 135 (Aug. 7, '42). Growing demand for complete utilization of scientifically trained personnel. Natl. Roster of Scientific and Specialized Personnel rapidly detg. needs and allocating supply. Present problem, mechanism to supplement dwindling reserves in trained scientific men. Depleting universities to provide same now at danger point and threatens future supply. Temporary expedients insufficient. Long-range view for continuous replacement necessary to win. This war dominantly one of ideas. Successfully waged only by complete use of brains and technical *knowledge* combined with mech. instruments of war. Peacetime methods impose artificial limitations on producing new scientists. Author describes how teaching methods must be changed to fit vital and pressing needs for producing greater no. of men trained to think. Must conserve teaching manpower to realize objective. Colleges and universities can play their part only by keeping active staffs intact and maintg. teacher morale by recognizing this as dominant part of war effort. *Discussion: Ibid.* **96:** 318 (Oct. 2, '42). HARRY GRUNDFEST: Discusser recognizes importance of above phase, but points out other ways to alleviate existing personnel shortages in various fields of physics. Many in biol., chem. and geol. fields, qualified for teaching or war research in physics and not yet doing war work. New teaching personnel possible from refugee scientists barred from war research by non-citizenship. Many high school science teachers qualified to teach college courses. Inter-institution exchange of teaching personnel recommended. Bottleneck in full utilization of scientists in medical, agric. and chem. fields appears to be difficulty of converting peacetime research into actively fruitful war effort. Reasons given. Answers thereto summarized by Penfield from experience in Canadian and British war effort: Principle in democracy that govt. not omniscient or always wise. Leadership must develop spontaneously in every dept. of natl. life. New ideas, new efforts should break out in all walks of life, from laborer to industrialist and professor, like influenza epidemic. Am. Assn. of Scientific Workers developing activity to aid scientists in formulating and presenting war research projects. Results promising and other groups copying. Recommend to natl. authorities various steps to encourage and promote creative initiative by civilian scientists that new problems and types of research useful to war effort may arise on basis of peacetime skills.—*Ralph E. Noble.*

Present Policies and Activities of the U.S. Public Health Service. WARREN F. DRAPER. Mil. Surgeon **90:** 123 (June, '42). Modern war a total war. Basic duty of military authorities to keep soldiers healthy; of pub. health authorities to reduce and, if possible, elim. hazards unhealthful to civilians. For yr., many small communities little concerned re sewage disposal, water supply

and communicable disease control. Problem of continuous overcrowding hits small town's health facilities. They need federal financial and technical help. Getting both. First step, assignment of med. officers to 9 Army Corps areas to liaison between military and civilian health authorities therein. In '39, U.S.P.H.S. undertook san. reconnaisance surveys in Army maneuver areas. Teams of med. officer and pub. health engr. investigated water supply, sewage systems, local pub. health services and made san. inspection of restaurants; enumerated hospital facilities, health centers and med. and nursing personnel. These surveys constituted *pub. health* maneuvers. Reconnaisance work extended into present emergency and widened scope. 250 defense areas surveyed. Army mobilization and indus. expansion depleted regular state health staffs. In Feb. '41, Congress provided U.S.P.H.S. with funds to send immediate aid into areas. Subsequently $3,700,000 appropriated for san., pub. health and indus. hyg. services. U.S.P.H.S. immediately recruited professional personnel and sent them into state health depts. By Oct. '41, nearly 400 physicians, engrs., nurses and lab. technicians in-service trained and assigned to work in latter as own employees, but on fed. pay. From Apr. to Oct. '41, U.S.P.H.S. met most acute needs in 140 defense areas involving 900 separate communities, many for first time learning value of professional full-time pub. health services. Community Facilities Bill made $150,000,000 available to Fed. Works Agency to build hospitals, health centers, water works, sew. disposal plants, garbage and refuse disposal facilities in defense areas. In gen., U.S.P.H.S. priorities list rates safe water supplies and adequate sew. disposal, health centers, hospitals, pub. health labs., important in order given. Gen. policy to erect these facilities only where defense pressure greatest. First, town decides need after suggestion by local authorities or U.S.P.H.S. field officer. Since last war, U.S.P.H.S. studied causes of indus. disease, then built model indus. hyg. program. Social Security Act provided funds to put it into action, assisting 34 state health depts. to establish such units. Program objectives: (1) To recruit and train professional personnel; (2) to intensify and expand field and lab. research; (3) to augment services provided to indus. by state indus. hyg. units, (more than 20 mobile units (engr., chemist, doctor) in field over country); (4) to apply indus. hyg. to branches of Army and Navy employing civilians. Other activities relate to pub. health research and natl. nutrition. Doctor and nurse shortage and venereal disease, 2 further important considerations in job of making and keeping America strong.—*Ralph E. Noble.*

U.S. Public Health Service. ANON. Mil. Surgeon **90:** 708 (June, '42). *Rural Sanitation.* In co-op. with state and local health authorities, house-to-house community san. survey of small towns made in vicinity of Point Pleasant, W.Va., war-indus. area. Prelim. data indicated between 200 and 300 san. privies needed. 60% of premises needed new ones, 15% needed repair of old ones. Proposed WPA community san. project postponed pending state health dept. proof that project needed. Survey in progress will supply required evidence. Water supplies of all rural homes visited need improvements. Imminent occupation by thousands of defense workers make definite action imperative. *Community Sanitation:* Needs surveyed and projects prepd. providing privy bldg. and individual water supply improvements in 24 defense areas in Md., Va., W.Va., and N.C. Projects involve 13,500 san. privies and 8,400 water supplies. Est. cost, $831,522 and $542,818 resp. At present, no satisfactory and practicable formula devised for getting projects into operation. Sufficient WPA labor unavailable. Community Facilities Act funds unavailable for nationwide community san. program, unless possibly in certain communities prepd. to assume maint. costs. Need urgent in 200 defense areas. *Water Analyzed at Beaches:* During 6 wk., mobile lab. unit took and anald. water samples from Biloxi Bay and waters near Pascagoula, Miss., where beaches used recreationally by armed forces and war-indus. workers. Unit also detg. effects of possible poln. on

shellfish taken from area. *Ibid.* **91:** 366 (Sept. '42). *Community Sanitary Service:* Recent dysentery and other enteric disease outbreaks in military and war indus. areas compelled further emphasis upon adequate san. facilities therein. To provide same, affected communities requested funds available under Community Facilities Act, for constr. of san. privies and septic tanks, constr. and protection of wells and other emergency water supplies, collection and disposal of garbage. Insan. conditions existing in certain camp area cited. Involves several hundred unsafe wells and 500 insan. privies. U.S.P.H.S. San. Sec. and dist. office personnel assisting state and local officials in prepn. and submission of applications for emergency san. projects. Funds allotted two; applications in process for many others.—*Ralph E. Noble.*

El Paso Expands Utilities for Army Use. Anon. Eng. News-Rec. **129:** 166 (July 30, '42). Since '39, pop. of El Paso, which was about 100,000, increased by upwards of 40,000 military personnel and about 10,000 civilians, creating acute water supply and sewage disposal problems. Plans complete and money available for $485,000 sewage treatment plant and vital new lines, and $755,000 water treatment plant under construction. Projects being financed from plant and equip. depn. account of water and sewerage dept., with aid of Fed. Govt. Priority ratings major problem. Present supply derived from 16 wells with combined capac. of 20 mgd. and safe yield of 13 mgd. There are 7 pumping stations, 5 serving single wells, 1 serving 8 and 1 serving 3, each discharging into small covered reservoir where fine sand settles out. Only other treatment is application of Cl and NH_3 as water is pumped from reservoirs directly into system. Pressure and reserve assured by 6 covered storage reservoirs, with aggregate capac. of 70 mil.gal., riding on system. Automatic chlorination provided at discharge of each reservoir. Expansion of camps began in '40, increasing avg. pumpage from 9 to 12 mgd., and by '41, peak demand reached 16 mgd. This yr., peak expected to be 18 mgd. Pumping beyond 13 mgd. exceeds recharge ability, invites salt water intrusion and causes pronounced increase in hardness. As addnl. wells would decrease ground water at accelerated rate, recourse was had to Rio Grande R., which flows through El Paso. City entitled to 14 mgd. from this source, provided it buys, and retires from cultivation, land with equiv. water demand. Water, with 1500 ppm. turbidity and mineral content varying from 750 to 1600 ppm., will be diverted from Franklin irrigation canal directly into 10-mgd. treatment plant. After passing through trash screens, water will flow to low service pumps where $FeSO_4$ and Cl will be added and thence to primary clarifiers, providing 3-hr. settlement. Aerator of diffused air type located in flume leading to chem. bldg., equipped for applying lime, soda ash, activated C, $FeSO_4$, Cl and NH_3. Facilities for flocculation, secondary clarification, recarbonation and automatic pH control provided prior to filtration. Provision also made for subsequent recarbonation by underwater gas burners and probable stabilization by passage through bed of limestone or marble chips. Cl and NH_3 will be added at high-lift pumps. Completion contemplated in Mar. '43, dependent upon priorities. Interesting feature of existing sewage treatment plants and proposed extension is prepn. of $FeSO_4$ soln., for treatment with chlorinated copperas, from Fe turnings and H_2SO_4, which has been found to be cheaper than purchase of $FeCl_3$.—*R. E. Thompson.*

Man-Hours on Pumping Plant. Anon. Wtr. & Wtr. Eng. (Br.) **45:** 8 (July '42). Expansion of industries for war production has given rise to increased demands for water. Frequently necessary for water authorities to install additional pumping plant, or equip new stations, absorbing iron and steel for which authorization must be granted. Once control passed, little control of appliances installed. Water engr. can assist war effort by adopting equip. which calls for least skilled man-hours in production. Pumps but small part of pumping station equip. Prime mover and appendages, switchgear, lifting appliances, heating lighting, etc., embrace, in aggregate, more work in mechanics labor than pumps

themselves. Essential to concentrate on these items now. Not enough for engr. to issue usual specifications and leave mfrs. to bid for what they can supply. On whole, water engr. still calling for equip. to something like peacetime specifications.—*H. E. Babbitt.*

Water Supplies in the Post-War Period. ANON. *Abstracts from Official Circular (190) of Br. Water Works Assn.* Wtr. & Wtr. Eng. (Br.) **45:** 65 (Aug. '42). Position of water works industry and problems it will have to face in post-war world not confined to rural areas, but common to all water authorities. Three specific points referred to Br. Water Works Assn. are: (1) allocation of reservoirs and protection of gathering grounds; (2) water supply generally in rural areas; and (3) character of water as affecting its use by industry. Most of best sites for dams for impounding upland waters already appropriated, consequently scheme of rural development should be planned in relation to special adaptability of particular stream. Service reservoir situated as near as possible to area in which water to be distributed. Gathering grounds for upland sources generally of low value, suitable for afforestation and sheep grazing. Site for future impounding reservoir must carry with it, its contributory gathering ground; and any development on such area should be under proper control. Situation (in England and Wales) as regards rural water supplies improved enormously since '29. Now time to review situation in view of addnl. facilities provided by Parliament since that date. If rural councils are to see that all houses have satisfactory supply of wholesome water, doubtful whether technical staff to make anals. would be available and, in any case, cost to community would be prohibitive. Purity of streams affected by discharge therein of indus. wastes. Main difficulty in river poln. problem lack of suitable authority to enforce various acts. Certain industries have settled in areas where local water most suitable to their particular process. Problems with which industry concerned in relation to post-war period: (1) law relating to underground flow; (2) compensation water; (3) modernization of law relating to water supply; (4) by-laws and regulations governing distr. of water and prevention of waste and contamn.; and (5) creation of specialized water dept. of an appropriate Ministry.—*H. E. Babbitt.*

STREAM POLLUTION AND ITS CONTROL

A Study of the Pollution and Natural Purification of the Scioto River. R. W KEHR, W. C. PURDY, J. B. LACKEY, O. R. PLACAK AND W. E. BURNS. U. S. Pub. Health Service, Pub. Health Bul. 276 ('41). Survey undertaken to obtain definite measurements of transformations occurring in stream following major changes in poln. intensity and to obtain data on natural purif. rates in smaller stream. Hydrometric, bact., chem., plankton and bottom sediment studies made of Scioto R. for 115 river mi. below Columbus, Ohio, during 30 mo., involving 3 types of sewage treatment at Columbus, point of heaviest poln. Periods and types of treatment were: (1) 10 mo., overloaded trickling filter; (2) 8 mo., plain sedimentn.; and (3) 12 mo., activated sludge. Times of flow detd. for river stretch between Shadeville and Red Bridge, 8 and 25 mi. respectively, below point Columbus sewage effluent enters. River channel cross-section, with soundings at low water, made, and mean velocity detd. from discharge and mean river cross-sectional area. Bact. and chem. data grouped according to 3 temp. and 5 discharge ranges and, additionally, over upper half river, for 3 periods of varying poln. at Columbus. Bact. decrease rates in river linear when semilog plotted for Shadeville to Red Bridge stretch and, roughly, at low stages downstream. At progressively higher discharges bact. decrease rates less in relatively less pold. lower half of stream; greater at higher temps. and in approx. range of previously observed rates on Ohio and Ill. Rivers.

B.O.D. decrease rates in Shadeville to Red Bridge stretch greater at low than high temps. No. of related factors discussed. D.O. profiles at different temp. and flow ranges, and periods of varying poln., form nicely graduated set of oxygen sag curves. Extensive series of re-aeration calcns. presented, but computed values for max. atmospheric re-aeration rates quite variable. Both chem. and bact. data indicated poln. in this stretch, during second period, much greater than expected, considering relative amts. B.O.D. discharged at Columbus during first and second periods. Poln. in stretch during third period relatively about same as first. Neither plankton nor bottom sediments reflected conclusively changes in amt. of poln. at Columbus resulting from changes in type of sewage treatment. Scioto proved highly productive of plankton algae and protozoa, exceeding, both in variety of species and total plankton vol., that of previously reported streams. Using entire groups of organisms as poln. indicators found fallacious, but certain species sufficiently selective of environment to indicate presence or absence of poln. Bottom sediments from stable record of avg. qual. of water in stream during period formed. Careful exam. of phys. properties and biol. content of such sediments gives reasonably accurate picture of avg. stream conditions. Composite picture obtained from such exam. must, however, be used, as certain factors, like downstream transportation of egg capsules, will result in temporary presence of small nos. of foul-water organisms in clean water environment. —*Ralph E. Noble.*

Delaware River Pollution and Analytical Studies. F. W. Kelly. (*Published in abstract only.*) Sew. Wks. Eng. **13:** 37 (Jan. '42). Anal. study of poln. in navigable Del. R. water made by U.S. Engrs. in '39–'40. Samples taken weekly at 14 stations from Trenton, N.J., head of tidal influence, through Philadelphia-Camden metropolitan area to Reedy Is., opposite Port Penn, Del., 80 mi. Tests included those for D.O., B.O.D., total and suspended solids, org. matter, alky., pH, total bacteria and *Esch. coli*. Graphical results clearly indicate deg. of poln. in various stretches at different temps. Zone of recovery from effects of raw sewage and ind. waste discharges from Philadelphia-Camden area found. Results valuable for detg. deg. of sewage and ind. waste treatment necessary to eliminate gross poln. of Del. R.—*Ralph E. Noble.*

Long-Time Biochemical Oxygen Demands at Low Temperatures. Edward W. Moore. Sew. Wks. J. **13:** 561 (May '41). Most studies relating to biochem. oxidation have been made at relatively high temps. for obvious reason that most difficulties encountered through discharge of sewage into watercourses during periods of warm weather. Author points out instances in which ice-covered watercourses have become anaerobic through biol. action because of inability to renew oxygen sources. Problem also of interest with respect to the operation of treatment-plant processes during winter months. Therefore, expts. and studies reported in paper extended over long period of time and over wide temp. range, particularly between 0° and 10°C., to det. "whether numerical values of consts. of formulation as given by Theriault are to be regarded as applicable to all sewages and pold. waters or whether they are to be considered merely as statistical avgs. from which values of any individual sewage or pold. water may differ substantially." Three series of expts. run, the first 2 using dild. solns. of settled domestic sewage in both bicarbonate and phosphate diln. waters according to std. methods of water and sewage anal. Third series run on undild. samples from each of 2 moderately pold. local streams. No. of charts and tables presented by author to show results of expts. and to present data on which he draws following conclusions: (1) First stage of B.O.D. well represented by modified unimolecular relationship of Phelps and Theriault, when account taken of lag period. Exceptions to rule occur in some expts. at and below 5°C., where there appears to be secondary rise in oxygen demand. (2) Value of k, the rate const. for first stage B.O.D. at given temp., should be considered as statistical avg.

rather than as true const. In some pold. streams its value may be much lower than generally accepted value, and in some sewages much higher, at least when they are incubated in std. diln. waters. (3) Effect of temp. on values of k and L for first stage adequately represented by equations developed by Theriault. However, numerical coefs. of equations found in studies have reported somewhat different from those given by Theriault. Differences particularly notable in values of k for expts. at or below 5°C., which are considerably lower than those predicted by Theriault's equation. (4) Second or nitrification stage of B.O.D. greatly retarded at low temps. and development becomes uncertain and irregular. At higher temps. can be formulated by unimolecular relationship, with lag period. Some values of const. k for this formulation given.—*P.H.E.A.*

The Significance of Plankton in Relation to the Sanitary Condition of Streams. J. B. Lackey. *Symposium on Hydrobiology.* Univ. of Wis. Press ('41). p. 311. Streams of Ohio Basin closely surveyed in 4-yr. study during which species and numbers of algae and protozoa in more than 3,000 samples, both preserved and unskilled, carefully examd. Many streams had single series of samples taken over whole stretch for study, while others systematically sampled at certain stations each week for periods covering many months—more than 2 yr. in case of Scioto R. Anals. of plankton content correlated to environmental factors as temp., rainfall, compn. of water trade and domestic wastes. All groups of algae found and all groups of Protozoa, except Sporozoa. 448 genera or species of micro-organisms counted, but only about 20% of these occurred with sufficient frequency to be expected in any random sample. Some species occasionally attained large numbers for very short time in a particular location or stream. Factors responsible for such blooms virtually impossible to define. Some species largely independent of wide range of environmental fluctuation and extremely tolerant. Some few species, however, responded sharply to poln. or the lack of it, and such species become useful indicator organisms. About 20 genera found which favored highly pold. water and about as many which disappeared quickly in pold. stream stretches. Last group includes virtually all yellow and olive-green flagellates, Chrysophyceae and Cryptophyceae. No other whole groups found which could be used as indicators. During Scioto R. investigations sewage of Columbus received 3 kinds of treatment: trickling filter, primary sedimentation, and complete treatment. River plankton failed to show marked differences for each treatment type, only slight general changes being noticeable. Organisms measured, and avg. sizes detd., then their vol. computed in ppm. These highest at temps. of 20°C. or more, when water low. At one time, Scioto at Commercial Point contained 5,998 ppm. by vol. of plankton—about 0.06%. Concns. as high as 32,933 ppm. have been found, at times of blooms, and water at such times actually green.—*P.H.E.A.*

The Effect of the Sewage From Nashville Upon the Plankton Population of the Cumberland River. Floyd J. Brinley. J. Tenn. Acad. Sci. **22:** 179 (Apr. '42). Cumberland R. shows clearly effect of isolated source of heavy poln. upon comparatively clean stream. Plankton pop. above Nashville avgd. less than 500 ppm., and D.O. high, around 10 ppm. Plankton vol. showed sudden increase below Nashville, reaching peak of 8,200 ppm. at Cress Ferry, falling rapidly to Dam B and gradual decrease to about 100 ppm. at Dam C, about 80 mi. below Nashville. Oxygen curve shows distinct drop at Dam 2, reaching min. of 0.70 ppm. at Nashville. Recovery slow and not complete for 50 mi. below Nashville.—*P.H.E.A.*

Toxicity of Sodium Pentachlorophenate and Pentachlorophenol to Fish. C. J. Goodnight. Ind. Eng. Chem. **34:** 868 (July '42). Sodium pentachlorophenate becoming increasingly important commercially as preservative for paper and wood pulp. Certain amt. escapes into streams as waste. Studies reported show that both sodium pentachlorophenate and pentachlorophenol fatal to more sensitive species of fish above 0.2 ppm., though

hardier species will survive at 0.4 to 0.6 ppm. Gradient tank tests showed that fish could not detect fatal 5 ppm. concn., and thus entered water contg. fatal amts., but did detect 10 ppm. Toxicity greater at lower pH. Within reasonable limits, size of fish, temp. and character of water have no great effect on toxicity. Eggs of lake trout very resistant to these compds., but lake trout most sensitive in yolk sac stage. Invertebrates such as serve as food for fish more resistant. Tests made in standing and running water and in gradient tank. Sodium pentachlorophenate menace may be removed by passing water through activated carbon, by extended exposure to light and air, or by sufficient diln. in streams.—*Selma Gottlieb.*

Recent Contributions to the Study of Industrial Waste Treatment. DONALD H. BARRACLOUGH. Surveyor (Br.) **99:** 147 ('41). Acidic wastes, chiefly from pickling of iron and steel, neutralized with lime. Metallic wastes, such as from plating solns. or from rayon mfr., recovered by pptn. of metal before dumping. Wastes from canning plants usually coagulated and filtered. Textile wastes being studied for clarification before going to sewage plant. Waste liquors from tanneries treated in Dorr clarifiers. Dairy wastes treated by Guggenheim process or by activated sludge process. Sulfite waste liquor, after neutralizing and freeing from gases, added to vegetable matter (cereal, straw, etc.) on which fermentive cultures have been grown. After fermentation liquor withdrawn for recovery of EtOH. Phenolic wastes extracted with esters of fat acids, preferably butyl acetate, or phenols may be recovered either by distn. or by extn. with alkali.—*C.A.*

Treatment of Vegetable Cannery Wastes. N. H. SANBORN. Ind. Eng. Chem. **34:** 911 (Aug. '42). Approx. 25 gal. of waste water contamd. with org. matter produced per case of 24 No. 2 cans of most vegetables, though waste in canning tomatoes or tomato products may vary from 3 to 100 gal. per bu. of tomatoes. Total waste from canning of vegetables in '40 approx. 4 billion gal. exclusive of cooling tank water. In addn., location of vegetable canneries in small communities and seasonal operation produce problems peculiar to canning industry. *Wastes:* (1) Cooling tank water: Contains little or no org. matter. Should be discharged directly to stream or sewer since value as diluent of stronger wastes does not justify cost of larger treatment plant. (2) Pea or corn silage juice: 5-day B.O.D. of 61,000 to 78,000 ppm. for peas and 30,000 for corn. pH about 4. Silage juice should be collected in underground tanks for final disposal by dumping in isolated places or slow discharge at times of high stream flow. (3) Gross solids: Solids, other than used for silage, obtd. from discarded raw material, trimmings, cleanup operations and screenings. Usually returned to fields, dumped in isolated spots, or given to farmers for hog or cattle feed. (4) Processing water: From washing operations, blanching, spillage around fillers and cleanup operation, contains dissolved and suspended org. matter. After screening, 5-day B.O.D. of pea, corn or tomato waste is 1000 to 4000 ppm. *Treatment:* (1) Screening: Essential regardless of further treatment. (2) Chem. pptn.: Both continuous-flow and fill-and-draw treatment used. Coagulants used are high-calcium hydrated lime, followed by copperas or alum. Coagulation at pH 10 to 11, and requires chem. dosages higher than for domestic sewage. Typical dosages range from 4 lb. of lime and 1 lb. of alum per 1000 gal. of screened tomato waste to 9 lb. of lime and 8 lb. of copperas for 1000 gal. of corn waste. If properly conducted, chem. treatment will effectively remove suspended and colloidal solids but not dissolved substances such as sugars. Fill-and-draw treatment elims. some difficulties of continuous-flow type of plant. For 2-line cannery, constr. cost approx. $3000, and operating costs, including all fixed charges, 1 cent per case of 24 No. 2 cans of peas. Sludge discharged to sludge beds. (3) Biological filters: Relatively few operated by canners due to large initial cost, necessity for conditioning prior to canning season and unfortunate experiences with overloaded filters. In overloaded filters, pH control with lime not satisfactory, since CO_2 pro-

duced in filter ppts. lime as $CaCO_3$. Soda ash can be used with considerable improvement in filter capac. and effectiveness. (4) Impounding: Odors cannot be successfully controlled by activated carbon, lime or clorinated lime, but sodium nitrate can be used. In expts. described, odor from lagoon treated with sodium nitrate did not extend beyond 200′ from lagoon. Lagooning and filtration can be combined. (5) Discharge to munic. plants presents problems since vol. and strength exceed that of domestic sewage in nearly all communities where canneries located. With untreated waste, pH adjustment necessary. Studies in Wis. indicate that min. of 80 cu.ft. of filter media per lb. of 5-day B.O.D. required on std. filters to secure satisfactory treatment. Munic. treatment most desirable soln. of problem but much technological information must first be gathered.—*Selma Gottlieb.*

Chemical Treatment of Trade Waste. *Laundry Wastes.* FOSTER DEE SNELL AND J. MITCHELL FAIN. Ind. Eng. Chem. **34:** 970 (Aug. '42). Laundry studied produced daily max. of 75,000 gal. of waste water from family wash. Fair avg. probably 60,000 gpd., 4 days per wk. Best treatment proved to be 360 ppm. of commercial alum and 144 ppm. of H_2SO_4. Substantially clear effluent obtd. Org. solids reduced 71 to 83%, total residue 27 to 45%, and oxygen consumed, 92 to 92%. Waste water leaving plant through heat reclaimer flows into sewer where chems. are added in mixed 5% soln. Waste then flows into mixing chamber just outside bldg. and then into 30,000 gal. rectangular settling tank with triple hopper bottom. Lead-in pipe discharges into delivery box open at bottom, and effluent overflows at opposite narrow end. Expected max. vol. of sludge 5% of 75,000 gal. Sludge pumped onto 4 sludge-drying beds located on ground. Some soil drainage occurs but most water removal is by evapn.—*Selma Gottlieb.*

Purification of Arsenious Waste Waters. S. N. CHERKINSKIĬ AND F. I. GINZBURG. Vodos. Sanit. Tekh. (U.S.S.R.) **16:** 1:49 ('41). Investigation on treatment of wastes contg. arsenic from mfr. of Paris green and calcium meta-arsenite, which contain 362 mg./l. of arsenious oxide, showed that addn. of 0.85 g. of ferrous sulfate and 2.25 g./l. of calcium oxide reduced content of arsenious oxide to 15-20 mg./l. Prelim. settling advantageous and addn. of calcium oxide alone gives less voluminous ppt. High residual concn. of arsenic makes it necessary to mix waste water with other wastes before discharge.—*W.P.R.*

Catalytic Oxidation of Sulfite Waste Liquor by Atmospheric Oxygen. IRWIN A. PEARL AND HENRY K. BENSON. Ind. Eng. Chem. **34:** 436 (Apr. '42). Immediate chem. oxygen demand (O.D.) due to easily oxidizable S compds. is only O.D. of consequence when sulfite waste liquor discharged into sea water. Subsequent gradual O.D. probably due to biochem. oxidation of easily oxidizable org. matter and to slow biochem. oxidation of lignin residue. Activated carbon effective catalyst for oxidation of chemically oxidizable compds. in sulfite waste liquor by aeration. Activated carbon supplied by Carlisle Lumber Co. of Seattle was 6-8 mesh granules. Soln. aerated while in contact with carbon. Carbon reduces foaming during aeration thus making possible much higher air velocities. Activity did not decrease with time during test period of 5 wk. Unsatisfactory results on several other catalysts reported. Carbon appears to act as carrier for oxygen. Immediate chem. O.D. of waste liquor reduced from 135 to 0 in 5 min. when aerated in presence of activated carbon; after 10 min. liquor contd. 14 ppm. of D.O. Sulfite eliminated. Can be used as batch or continuous process.—*Selma Gottlieb.*

By-Product Phenol Recovery. Anon. Gas World **115:** *Coking Sec.:* 92 ('41). Discussion of chief methods used for recovery of phenol from waste waters from carbonization processes. Most common method by use of solvent which must have following properties: must be cheap and must have considerable solvent power for phenol, non-soly. in ammonia liquor, and density substantially different from that of ammonia liquor; must also be easy

to recover phenol from it. Several solvents satisfy these conditions, those most frequently used are benzole and tricresyl phosphate. Necessary to expend some materials and energy to recover phenol; in pre-war years recovery generally profitable when concn. of phenol 0.4 g. or more per 100 ml., and carried out at a loss when less than 0.1 g. per 100 ml. present. Majority of existing recovery plants use benzole to extract phenol. Phenol recovered from benzole by distg. off benzole or by washing phenol-benzole soln. with caustic soda to produce aq. soln. of sodium phenolate. Distn. more expensive and results in greater loss of benzole, so use gradually reduced. Ammonia liquor leaving washing column carries with it certain amt. of dissolved benzole. Amt. of benzole lost in this way may be as much as half amt. of phenol recovered. Methods used for recovering this benzole include: (1) distn.; (2) blowing air and steam through liquor and condensing the benzole; (3) washing liquor with aliphatic brown coal-tar oil; and (4) removing benzole with active carbon and subsequently recovering it by steaming. Tricresyl phosphate, use of which has been patented under trade name "Triphos," dissolves phenol more readily than does benzole, has solv. in ammonia liquor only about $\frac{1}{30}$ of that of benzole, and dissolves higher tar acids; sepn. of the dissolved phenol by distn. very simple. Process now in use at five plants in Germany. In Britain, experience with extraction of phenol with dephenolated tar oils unsatisfactory, but in U.S. extraction of 93% of phenol obtained, and at plant in Germany content of phenol in gas liquor reduced from 0.8 to 0.3%. Active carbon only solid adsorbent used for recovery of phenol and, as far as known, used at only one large plant. Advantage is that it is able to deal with liquor contg. very small amts. of phenol. Recovery of phenol with various types of inert gases proposed, and at plant designed and built by Am. Koppers Co. partially distd. ammonia liquor sprayed down column to meet stream of steam and air or inert gas. Said that 95% of phenol in original liquor recovered. Similar processes have been in use in Germany for some time.—*W.P.R.*

Recovery of Chemicals From Pickling Liquor and Copperas Waste. HARRY W. GEHM. Ind. Eng. Chem. **34:** 382 (Mar. '42). Pickling liquor, consisting of solns. of $FeSO_4$ and H_2SO_4 can be treated to yield Na_2SO_4 of high purity, and $FeCl_3$ in solns. up to 24%. To produce Na_2SO_4 in lab. expts., soln. treated at 70°C. with sodium silicate soln. followed by solid soda ash, stirred 20 min., filtered, and washed twice. Filtered readily. Filtrate contained 16.7% Na_2SO_4, a satd. soln. at 20°C. Anhydrous salt obtained by evapn. was 99+% pure, iron-free and pure white. Filter cake, SO_4-free, contd. 65% moisture, but crumbled readily, and in 30 hr. at room temp. dried to 3% moisture. Anal., 41.40% iron oxide and 39.08% silica. Perhaps usable as part of ore charge to blast furnace for iron recovery. To produce $FeCl_3$, liquor reacted with scrap iron to neutralize most of free acid, and treated, while stirring, with $CaCl_2$ to yield $FeCl_2$ and $CaSO_4$, filtered, washed, and filtrate chlorinated. Iron recovery 87% or better and $FeCl_3$ obtained relatively low in impurities. $CaSO_4$ cake remaining has possibilities as bldg. material.—*Selma Gottlieb.*

Settleable Solids in Raw Sewage. JOSÉ CAPOCCHI. Revista Bras. Quim. (Brazil) **12: 67**: 21 ('41). Agreement of many authors upon difficulty of taking really representative samples of avg. compn. or raw sewage in 24 hr. Author makes composite avg. of results obtained in individual assays, instead of composite avg. sample, in this way avoiding sources of error and enabling easy establishment of sewage avg. concn. with sufficient accuracy. Taking into consideration hourly variation of flow (q, q_1, q_2, etc.) author adopted avg. of 24 (n) hourly detns., results of which expressed (c, c_1, c_2, etc.) in ml./l. of settling solids (Imhoff cone), transformed into ml. per sec., according to formula:

$$C = \frac{cq,\ c_1q_1,\ c_2q_2,\ \cdots}{nQ}$$

where Q is avg. flow and C, avg. concn. Author presents graph with data of '40 from Ipiranga (Sao Paulo). Method not yet exptly. verified.—*Ed.*

Relation of Disposal of Sewage and Water Purity as Exemplified in Toronto's Problem. NORMAN J. HOWARD. Can. Engr.—Wtr. & Sew. **80:** 6: 21 (June '42). Poln. of Lake Ontario at Toronto discussed. Situation in regard to raw water quality improved since opening of new Victoria Park water purif. plant, as water may be drawn from any of 3 intakes according to prevailing quality. Under unfavorable meteorological conditions (wind direction), however, poln. present at all 3 points of supply. Constr. of modern sewage treatment plant approved by city council, but project delayed by inability to secure necessary steel. Chlorination of effluent from present disposal plant investigated as temporary means of alleviating poln. of lake water. Tests made in '32, '39 and '42 showed that Cl demand of effluent varied from 3.5 to 25 ppm., depending upon time of collection. Avg. of most recent detns., 15 ppm. Application of that amt. of Cl in lab. to samples of effluent reduced no. of bacteria from avg. of 2,120,000 per ml. to 6,650 after 10-min. contact and to 2,445 after 30-min. contact. Coliform bacteria reduced from 100,000–1,000,000 per ml. to 245 and 277, resp. When chlorinated samples allowed to stand for 24 hr. at 70°F., bact. content increased to in excess of 100,000,000 per ml.; when allowed to stand at 44°F., counts approx. doubled in 24 hr. Similar multiplication might occur following discharge of chlorinated effluent into lake when water warm. Treatment of 70 mgd. with 15 ppm. Cl would cost approx. $150,000 annually, equiv. to carrying charges on capital expenditure of $6,000,000 at interest rate of 2.5%. Such treatment, of course, would in no way alleviate sludge problem and would not reduce present water treatment costs. Constr. of new treatment plant only solution.—*R. E. Thompson.*

WELLS AND GROUND WATER

Base-Exchange and Sulfate Reduction in Salty Ground Waters Along Atlantic and Gulf Coasts. MARGARET D. FOSTER. Bul. Am. Assn. of Pet. Geologists **26:** 838 (May '42). Salty waters encountered in water-bearing sands along Atlantic and Gulf coasts apparently not simple mixtures of ground water with more or less sea water. When compared with theoretical mixtures of fresh ground waters and sea water, former from comparable depths in same formation, and amt. of sea water being that indicated by chloride contents of salty waters, natural salty waters found characteristically lower in Ca, Mg, and SO_4, higher in Na, suggesting waters undergone base-exchange and reduction of SO_4. Indicated replacement of Mg and Ca in salty waters by Na from base-exch. minerals in sand, suggests base-exch. minerals not in equilibrium with present day sea water or salty waters formed by its admixture with fresh ground waters in which Na bicarbonate predominant. These relations further suggest water-bearing sands some time flushed of salt water, at least to point farther down dip than present, by water having lower Ca/Na and Mg/Na ratio and that salt water now contamg. fresh water is new advance of former inland. Low SO_4 content of salty waters attributed to reduction of SO_4 but whether causative agent living micro-organisms or inaminate org. matter, or whether reduction occurred when sediments deposited or later, cannot be definitely proved now. Parent salt waters of salty waters may have been connate waters in which SO_4 reduced, as latter known to take place in environmental conditions like those under which some sediments laid down in Coastal Plain. In flushing implied by low Ca-Mg content of waters, connate waters perhaps forced seaward but incompletely flushed from beds. Subsequent lowering of fresh-water head, relative to sea-water head, possibly permitted connate water movement farther inland. Unselected salty waters from widely different geographical and geological sources in Atlantic and Gulf Coastal Plain, apparently having undergone similar alterations in mineral compn., indicate causative conditions which are general throughout the entire area.—*Ralph E. Noble.*

Differential Density of Ground Water as a Factor in Circulation, Oxidation and Ore Deposition. JOHN S. BROWN. Econ. Geol. **37:** 310 (June-July '42). Differences in densities of natural ground waters sufficient to motivate their circulation in certain cases without aid of piezometric or artesian head. Likely such densities developed in vicinity of oxidizing ore masses where substantial amts. of heavy salts taken into soln. Solns. enabled to descend well below water table producing oxidation, enrichment or soln., as chem. reactions with wall rock tend to replace heavier elements with equiv. lighter ones. Data for simple chem. solns. and actual mine waters presented to support view. Variations in density of ore-depositing magmatic solns. probably even greater and more important.—*Ralph E. Noble.*

An Electrical Basis of Water Divining? ANON. Wtr. & Wtr. Eng. (Br.) **44:** 60 (Mar. '42). As to water alone, diviners claims limited to water flowing naturally or existing underground and affected only by liquid water underground. Many diviners said effects claimed caused by magnetism or electricity. Earth currents total approx. 1,000 amp. for world's surface in normal fine weather. Ionospheric continuous current at height of about 70 km. amts. to 200,000 amp. at poles, increasing to more than double occasionally. There are stray currents from power and telegraph installations. Two forms of current in earth: one caused by spontaneous electrification owing to oxidization of sulfide ore body in presence of moisture; while other natural earth current system, an a-c., with periodicity of 2 cycles per day. Airman stated he could always tell when he was crossing river, although it might not be visible to him.—*H. E. Babbitt.*

Sand Removal From Well Water. G. L. FUGATE. W. W. & Sew. **89:** 161 ('42). Houston, Tex., believed to be first public water supply to install Brassert automatic self-cleaning sand strainer to prevent entry of sand from aquifer to system. Straining unit consists of hollow cone drilled with holes in which screening media inserted; external motor rotates strainer in 24″ housing; washout slot is opposite row of strainer holes. Sand accumulating on screening disks flushed out by a reverse flow of clean water from inside conical drum as area is lined opposite washout orifice. When first operated, strainers clogged rapidly owing to wedging action of sand grains and insufficient pressure for dislodgment by low-pressure wash. Connection to high-service pumps with automatic control, with pressure differential between feed and drain sides with time relay to hold valve open for entire revolution of screen drum proved effective. Device prohibited as cross-connection, but later allowed when well water chlorinated to 1.4 ppm. residual to control gelatinous growths. Pre-chlorination noted to reduce tendency of sand to clog strainers. Operating cost is \$0.48 per mil.gal.—*C.A.*

Well-Water Treatment. H. M. MATHEWS, M. G. STEWART AND F. K. ELLIS. J. Southeast. Sec. A.W.W.A. **10:** 28 ('41). Thomasville, Ga., well water has 192 ppm. soap hardness and is treated with lime, soda ash and fuller's earth and sent through a clarifier. Water, which then has a caustic alky. of 40 ppm., sent through carbonation, sedimentation, and final carbonation to 4 to 6 ppm. bicarbonate. Pre-chlorination used. Final hardness reduced to 70 ppm. Natchez, Miss., well water contains 80 ppm. CO_2 and is aerated, sufficient lime added to give a caustic alky. of 20–30 ppm., ferric sulfate added for coagulant and finally carbonated. Sumter, S.C., well water treated with 4 ppm. of sodium hexametaphosphate, aerated and 25 ppm. of NaOH added. Eliminated trouble from iron and CO_2.—*C.A.*

Rejuvenating Wells With Chlorine. HERBERT L. WHITE. Civ. Eng. **12:** 263 (May '42). By simple treatment has proved feasible to renovate 2 sluggish wells built for Univ. of Ill. Well No. 10 about 160′ deep with shutter screen 26″ in diam. and 55′ long. Specific capac. (s-c.) of well in '35 about 100 gpm. but had decreased until in '40 only 24.5 gpm. per ft. of drawdown. When well pump not in operation well contains about 40′

water. Seemed probable that reduction in capac. due to deposits of $CaCO_3$ on screen or in gravel adjacent to screen. To correct this proposed to treat well with acid and to surge it. Over 400 gal. of 20° Baume commercial muriatic acid emptied into well. S-c. increased from 24.5 to 38 gpm. Not satisfactory so chlorinator installed to discharge highly chloriated water through ½″ galv. iron pipe into well near bottom. S-c. increased from 38 to 50.2 gpm. Increase indicated most of difficulty due to some org. growth. Chlorine tried on well No. 11 and s-c. increased from 34 to 60 gpm. Then treated with same quant. muriatic acid in same manner as well No. 10. Acid treatment increased s-c. from 60 to 66 gpm.—*H. E. Babbitt.*

Acid Treatment Quadruples Flow in a War Plant Water Well. ANON. Eng. News-Rec. **129:** 232 (Aug. 13, '42). 10″ well drilled to depth of 901′ through limestone, chert, dolomite and sandstone, ending up in water-bearing stratum of mixed sandstone and dolomite, permanently cased to depth of 335′. Upon completion, water rose to within 65′ of surface, but flow avgd. only 166 gpm. Electrograph, which reveals location, with accuracy of less than 1′, of water, oil or other deposits that may not have shown up in drilling, due to "mudding out," indicated water in several sandy dolomite formations penetrated. Well therefore treated with HCl contg. corrosion-inhibiting agent, sufficient quant. of mixt. being introduced under pressure over period of about 2 hr. to give acid concn. of 15%. Water then pumped in under pressure of 10–25 psi. to force acid into rock, where it was allowed to remain several hr. Finally, all trace of acid removed by steady pumping. Yield of well increased to nearly 1,000 gpm.—*R. E. Thompson.*

Practical Precautions in Management of Subterranean Water Sources. W. H. MAXWELL. Contractors' Rec. **52:** 726, 748 ('41). Discussion of poln. and protection of underground sources of water. Knowledge of geology of locality necessary for protecting underground water. Poln. may occur during rainy periods after periods of drought, during which polg. matter has accumulated on surface of gathering grounds. In areas of chalk and limestone, drainage from swallow holes and fissures may leave one river catchment and enter another. Causes of various typhoid epidemics discussed. Underground passages common in limestone formations and through these water travels rapidly; through fissures and swallow holes impure water may reach pumping station very rapidly after heavy rain. Purchase of gathering area so that it can be controlled by water authority best means of preventing poln. Legal aspect discussed. Where borings being sunk, supplies from sources in vicinity should be discontinued, or, if this is impossible, all water should be treated with coagulant, filtered and sterilized before use. Recommendations made for preventing introduction of poln. from workmen's clothing or by carriers of typhoid. Water derived from sandstone strata purer than that from limestone, since sandstone acts as filtering medium. Poln. may arise from borings for oil in vicinity. Metal tube bore linings not effective safeguard, as they have very short life in corrosive waters. Depletion of yields by industrial demands may make methods of conservation necessary. Underground supplies may be replenished by discharging surplus spring water down existing boreholes or by discharging surplus potable water from another source over porous ground or on outcrops of water-bearing formation. Water conserved by second method of "water-spreading" should be as free as possible from suspended or colloidal matter to avoid clogging pores of soil. Depletion of water levels in London area by continuous pumping has caused infiltration of brackish water from tidal parts of Thames. Author considers that water from chalk in London basin should be under constant examn. and should always be chlorinated. Yields can be estd. satisfactorily only from records, kept over years, of variations of water levels and borings and of local rainfall. Limits for size of protective areas required to protect sources of supply difficult to fix since underground water may travel long distances in short time. Even when

borings metal-lined to considerable depth, liquid from defective drains, sewers, or old cesspools may find way downwards through loose strata round outsides of bore linings; sealing by cementation under pressure should be carried out to considerable depth and supply should be filtered and chlorinated.—*W.P.R.*

Underground Water Supply Complicates Bridge Pier Construction. W. H. Townsend. Eng. News-Rec. **128:** 495 (Mar. 26, '42). Peoria Water Works Co. obtains supply from wells extending into sand and gravel stratum carrying underground flow. Stratum separated from Illinois R. flow and ground water by layers of clay and shale of varying thickness. Tests indicated that 20′ head of water required to penetrate seal. In planning highway bridge across river, test well observations indicated that piling for 4 piers would extend into stratum drained by company's wells. Areas involved dewatered to riverbed el. inside deep-web cofferdam sheet piling to prevent infiltration into underground stratum and concrete seals up to 14′ thick poured after foundation piles driven.—*R. E. Thompson.*

Sandstone Water Supplies of the Joliet Area. Anon. Illinois State Water Survey Bul. No. 34 ('41). Report on well water supplies in the Joliet-Wilmington-Morris area includes munic. and indus. well water supplies. Enumerates 49 supplies obtained from 92 wells drilled into St. Peter, Galesville, and Mt. Simon sandstones, and 7 of shallower depth. Report prompted by increasing demand in various municipalities accompanied by steady recession of water level and greatly increased demand occasioned by constr. of Kankakee Ordnance Works and Elwood Ordnance Plant some 8 mi. south of Joliet. St. Peter Sandstone separated from Galesville sandstone by considerable thickness of impervious material, also considerable intervening material between Galesville and Mt. Simon sandstone. Intervening materials, when undisturbed, not only keep sandstone separated, but also water that is stored in them. Each formation has its own hydrostatic pressure at any particular location. Galesville sandstone has thickness of about 100′ to 250′ and is found at depth of 1,350′ or more. Mt. Simon sandstone while prolific in yield produces water generally undesirable because of high salt content. Water levels have steadily receded in all deep sandstone wells not only in Joliet-Morris-Wilmington area but in metropolitan area of Chicago and at other heavily pumped areas throughout state. All available data indicate that water from any one formation at particular location is of distinct compn. which can be altered only by blending with water from other formations. Effectiveness of sealing wells important in controlling mineral qual. of nearby wells. Consideration of sandstone waters must involve casing records and possibility of more or less diln. with limestone water of qual. peculiar to vicinity.—*H. E. Babbitt.*

Infiltration Studies in the Pecos River Watershed, New Mexico and Texas. Hillard L. Smith and Luna B. Leopold. Soil Sci. **53:** 195 ('42). Artificial rainfall applied to 264 plots 12 x 30″ representing various soil and vegetal types in Pecos watershed. In general, soils shallow, calcareous, heavy in texture and of pH range 7.6 to 8.5. Investigation showed highly signif. pos. linear correlation between final infiltration rate and vegetal density. Rate of infiltration showed neg. correlation with dispersion ratio, amt. of dispersed clay, and silt and clay. The 5-mm. clay content showed signif. neg. correlation with final rate of infiltration.—*C.A.*

Tunnels for Increasing Honolulu's Artesian Water Supply. Pub. Works **73:** 29 (Jan. '42). Water for domestic purposes scarce in Hawaii because so much used for agric. Honolulu draws 34 mgd. from mountain sources by means of wells in artesian areas. By providing meters regularly tested per capita consumption reduced from 253 to 205 gpd. Expected that 2.6 mgd. potable water may be conserved by using non-potable water for air-conditioning and other commercial purposes. Several tunnels planned to make water more readily available to artesian well system. Tunnels

will divert portion of stream into mountains and will cause water to be stored in basaltic rock formation. Ground water level will therefore be raised and more water can be obtained from wells. One tunnel, 500′ long, increased supply by 0.4 mgd. Three proposed tunnels, one 500′ and two 1,000′ long, expected to increase supply by 4.6 mgd.—*P.H.E.A.*

The Ground Water Situation in Berlin Since 1870. J. Denner and F. Mosenthin. Gas u. Wasser. (Ger.) **81:** 734 ('38). Since 1869 ground water level of Berlin has been regularly surveyed. Since introduction of drainage, canalization of Spree, and other measures, ground water level has steadily fallen. Damage resulting from this fall in ground water level is mentioned. Measures for increasing flow of water to Spree and for avoiding fall in ground water level are suggested.—*W.P.R.*

Water Supplies in Tanganyika Territory. Anon. Wtr. & Wtr. Eng. (Br.) **42:** 398 (Dec. '40). In Northern Province, near Lolboro, bedrock is gneiss of Lower Basement Complex, with occurrence of isolated lava outcrops in vicinity of Lolboro. In Eastern Province, hydrological survey showed bedrock to be gneiss of Lower Basement Complex. Water struck but so far only 157 gal. (Imp.) per hr. have been obtained during 8-hr. test. In Central Province, bedrock of northeast Singida dist. consists largely of granite and, in many places, shallow water supplies developed, but majority of wells and water holes which were examined had been dug in the numerous "*mbuga*" and, in most cases, reached granite bedrock. During rainfall year, June '38 to May '39, effective rainfall, causing runoff into Dodoma res. 11.77″, being 79% of total rainfall. Res. empty for 7 days in Jan.—*H. E. Babbitt.*

Town Water Supply Installation at Naracoorte, S. Australia. R. G. Wilton. Commonwealth Engr. (Australia) **28:** 83 ('40). Residents of town (pop. 2,500) depended until recently on storage of rain water, supplemented by bores sunk into the polyzoal limestone which underlies the surface. These supplied water with hardness of generally over 40° (English). Municipal water supply now installed. Two bores sunk into deeper aquifer, sub-artesian storage known as River Murray Basin. Water of very high standard of bacterial purity, and relatively low hardness (about 24°). Boring equipment, pumps, and construction of water tower described.—*W.P.R.*

Deep Wells as a Source of Water Supply in the Province of Ontario. A. T. Byram. Can. Engr.—Wtr. & Sew. **80:** 6: 13 (June '42). In Ontario, 226 of 288 municipalities served by public water works systems own the supply works, and of these 142 derive supplies from surface sources and 84 from deep wells. Latter by no means confined to smaller communities. Since '22, no. of municipalities supplied from deep wells has increased 78.7%, i.e. from 47 to 84. Depth of wells varies from 30 to 600′. Soil formation of province consists to great extent of glacial drift and is very deep in some localities. Wells are of 3 common types, rock, single-casing screen and gravel wall. Latter used extensively and have given satisfaction. Common disadvantage of deep-well supplies is hardness of water. Three communities have built softening plants to correct this difficulty. Fe content objectionable sometimes also. One town, Orillia, has installed 2 wells recently to obtain palatable supply during summer months. Normally, supply drawn from Lake Couchiching, on which town located, but lake water comparatively warm and extensive treatment required to remove weedy taste during summer. Tabulations included giving details of artesian and deep-well supplies in province, including in some cases anals. of water obtained.—*R. E. Thompson.*

Water Supply Works in the Nyasaland Protectorate. Anon. Wtr. & Wtr. Eng. (Br.) **44:** 59 (Mar. '42). Combined water supply schemes for which grants totaling £75,430 received from Colonial Development Fund completed. Work of drilling units, since inception of schemes, included 68 boreholes completed, 23 abandoned, and avg. daily

yield of productive boreholes 23,744 gal. (Imp.). In Dowa dist., 2 boreholes penetrated gneiss bedrock at depths of 175′ and 198′, resp. Another borehole is 202′ deep, of which 190′ entirely in gneiss. Yielded 1,800 gal. (Imp.). per hr. over period 8½ hr., without lowering depth of water in borehole. Native well inspectors, all of whom have been trained in work of wells maint. by Geol. Survey now engaged in maintg. 529 wells and boreholes constructed during '30–'40. Inspection showed conditions generally satisfactory and manner in which villagers looking after wells continues to show improvement.—*H. E. Babbitt.*

DISTRIBUTION SYSTEMS—CONSTRUCTION AND MAINTENANCE

It's a Pipe to Save Labor. Norman J. Radder. Successful Farming **40:** 4: 11 (Apr. '42). Mfrs. of elec. farm water systems given priority rating on raw materials. Generally, min. capac. considered is 250 gal. per hr. based on requirements per human and animal unit. Size should always be based on day peak load and anticipate future expansion plus reserve factor of 10 to 15% addnl. capac. Usually, in small hydropneumatic sys., storage tank size 42 gal. of which only ¼ to ⅓ available as reserve supply. Where possible and practical, pressure tank should be set close to pump. Piping system from tank to outlets, should be provided with: pipe of sufficient size to give sufficient vol. with min. of friction; plan for preventing corrosion and air-locking; protection against freezing. Sharp turns should be avoided or "long-turn" fittings used to reduce friction and lessen chance for "water hammer." Liberal use of unions and shut-off valves facilitates repairs, changes and addns. Check and waste valve installed at high point in long underground line permits: (1) release of air which sometimes collects and reduces flow and (2) draining line to prevent freezing. With pump at well and tank at point of discharge, pump operates under extra pressure equal to vertical distance plus friction loss between pump and tank. Pump and tank at source most satisfactory, provided suction lift does not exceed 20′ to 25′ for shallow well pump. Combination system of hydropneumatic (pressure), gravity and free-flow, any unit of which would work separately, permits setting valves so pump will discharge into pressure tank, gravity storage tank or ditch. Deep well or "pit-type" pump installations may draw up to 400′ from water to discharge but pump must be directly over well. Best type if supply well close to foundation wall. In set-length type of deep-well installation, with pump above ground, set-length attached to drop pipe with discharge in lower end and must be below frost line.—*Ralph E. Noble.*

The Welding of Piping. Arthur N. Kugler. Heatg. & Ventg. **39:** 5: 55 (May '42) (*Abstracted* Jour. A.W.W.A. **34:** 1111 ('42).) *Ibid.* **39:** 6: 51 (June '42); **39:** 7: 53 (July '42). *Welding of Steel Pipe:* In forehand welding (old method) torch flame points ahead in direction of welding and welding rod precedes flame. To secure proper penetration and fusion, opposite oscillating movements imparted to both in semi-circular patterns. In backhand welding (newer method) torch flame points back at completed weld and welding rod interposed. Complicated oscillating motions unnecessary, hence narrowing of welding vee from 90° to 75° possible. Minimizes oxidation of weld metal and yields deposits of higher phys. properties. Indispensable procedure for successful vertical pipe position weld. On other hand, forehand welding only soln. in difficult place. In oxyacetylene welding, alloy steel rods afford tensile strength from 60,000 to 70,000 psi. with elongation from 20 to 30%. Weldability vastly superior, porosity virtually elimd. *Multi-layer Oxyacetylene Welding:* Single layer welds practical on pipe wall thicknesses up to ⅜″. When greater, size weld required makes proper root penetration and thorough fusion throughout difficult. Multi-layer welding faster, less costly, and of better qual. For pipe ranging from ⅜″ to ⅝″, 2 layers used; from ⅝″ to ⅞″, 3; from ⅞″ to 1½″, 4. For plain carbon

steel each layer should range from $\frac{3}{16}''$ to $\frac{1}{4}''$. Technique described. In welding h-p. piping, particularly carbon molybdenum steel, necessary to submit welded pipe joints to some form of stress relief to avoid locked up stresses. Procedure to heat weld and adjacent pipe material for distance not less than 6 times thickness to temp. 1,150–1,250°F. maintd. in ratio of 1 hr. per in. thickness. Heating and cooling rates carefully controlled. *Braze Welding Galvanized Steel Pipe:* Without special flux, braze welding of galvanized steel pipe burns off zinc (Zn) coating about 1″ each side of weld exposing zone to corrosion. New semi-liq. paste flux painted on joint in vee and inch or more along side of vee, internally and externally. Rods also dipped in flux or latter applied by mfr. Flux compn. controls volatilization of Zn coating and Zn content of brass rod, preserving corrosive resistance in joint equal to that of unaffected pipe itself. Also reduces porosity to negligible amt., yielding welds of high density, ts., and ductility. *Arc Welding:* Best results with shielded arc electrode. For econ. and qual. wise to select electrode best suited for given need. A.S.T.M. Specification, Serial Designation A233 – 40T, provides excellent information. Results with different types described. Deposits with certain electrodes possess high phys. properties and pass x-ray examn. *High-Pressure Piping:* Carbon molybdenum and chrome molybdenum electrodes available for welding steels of corresponding compn. Preheating by elec. resistance or induction exceedingly important here. Stress relieving also essential. Carbon molybdenum electrodes classes E7010 and E7020. Former designed for all-position field welding; latter for flat position shop work with either d-c. or a-c. *Fittings:* To realize max. benefits of welded piping, only fittings specially designed therefor should be used. Typical group illustrated; all designed for butt-welding to pipe. Butt-welded joint produces most satisfactory results. More recent development for small diams. of pipe illustrated. Advantage in fact unnecessary to prep. pipe ends specially for welding, and assembly such that not critical as to length of pipe insert within bore, provided it enters with sufficient amt. to give required bearing. Competent operator should be capable of fabricating fittings from std. lengths of pipe when necessary. To facilitate fabrication, reliable welding supply houses provide pipe templates giving lines of intersection of various elements of fitting, permitting their fabrication by oxyacetylene cutting and fusion welding. Fittings fabrication should not be attempted, however, unless accurate, proven templates used. *Qualification Tests:* On h-p. and/or high-temp. work, various state laws and insurance cos. regulations require qualification tests of welding operator's ability. Wise to check operators occasionally on any piping system. Cost of slow leak on l-p. system may far exceed cost of applying qualifn. test. For jobs when no existing code applies, simple tests prepd. by Int. Acetylene Assn. in pamphlet, "Rules for Selection of Operators of Welding Equip." Several codes re welded piping in state of flux. A.S.M.E. Boiler Code requirements closely follow Tentative Std. Qualifn. Procedure of Am. Welding Society (A.W.S.). A.S.A. Code for Pressure Piping, B31.1-'35, being revised. Finally will doubtless conform to requirements of A.S.M.E. and A.W.S. Latter's Tentative Std. Qualifn. Procedure covers all forms of process and welding operator qualifn. tests. A.S.M.E. Boiler Code governs all piping up to boiler shut-off valve inclusive. A.S.A. Code covers from that point out to points of ultimate use. *Testing:* Of even greater importance to test safe operating condition of finished welded pipe system. Instead of usual destruction tests, hydrostatic and x-ray tests used. Former applied to l-, m-, and h-p. welded lines by filling same with water, making certain *line free from air pockets*. Pressure then built up by hand or power pumps for test. Former used on small systems, latter on large. While under pressure, frequently require system subjected to hammer blows on pipe adjacent to weld in such manner to produce sharp vibratory stresses without permanently deforming pipe metal. Test pressure generally exceeds normal work-

ing pressure about 50%. If system long, requiring too much water for test, sometimes subjected to l-p. air test, about 100 psi. For h-p., high-temp. piping some specifications require x- or gamma-ray examn. to det. welding soundness by taking two oblique pictures of same joint. *Specialized Procedure:* Trepanning is destructive test used extensively as follows: Plug, including portions of welded and base metal, removed from welded connection either with circular saw leaving round hole, or special spherical saw leaving groove similar to single bevel grooved joint. In either case, plug polished and etched along edges to det. penetration soundness and fusion thoroughness. If unsound welding indicated, weld usually removed by oxyacetylene cutting and short pipe welded in its place. If satisfactory, trepan hole filled with weld metal. Sometimes circular hole threaded to receive threaded plug seal-welded around edges. *Non-Ferrous Piping:* Considerable detail given re joining brass and copper piping. Percentage metal compn. and proper temp. of braze welding specified. *Organization of Welded Pipe Job:* Careful planning required. Greater proportion of rolling welds, lower cost. As much work as permissible should be shop-fabricated. Transportation facilities may limit max. size of assembly handled economically. *Cost Estimating:* Labor and material comprise direct welding costs. Welding indus. practice to develop costs on "per joint" basis. Piping indus. bases cost ests. on "diam.in." Latter common denominator in calcg. costs involving no. of different pipe sizes. Equals 1" of nominal pipe diam. whether of 2", 8" or 45". Cost of welded joint, therefore, may be divided by no. of diam.in. to arrive at cost per diam.in. In actual practice, experience shows certain quants. of material required by welding crew for 1 day during which will produce, within certain range, given amt. of work. Tables show quants. of oxygen, acetylene and welding rods consumed by crew in avg. 8-hr. day. Author concludes welding of piping for all classes of service long since passed exptl. stage. No longer a substitute process but rather std. by which all other methods judged. After present war emergency, believes virtually all pipe will be welded because best method and abundance of fully competent operators.—*Ralph E. Noble.*

Control Welding Hazards. ANON. Safety Eng. **84:** 1: 34 (July '42). Increased no. of welding workers warrants constant and intelligent attention to associated hazards controllable by preventive measures. Typical ones: (1) eye injuries from brilliant light effects; (2) skin burns from arc or molten metal; (3) burns from handling hot wires, tools, rods; (4) illness due to inadequate ventilation causing metal fume fever, metal poisoning, "shakes." Arc emitted invisible rays burn skin and affect eyes. Latter trouble prevented by special lenses mounted in goggles, helmets and face shields. Fed. specifications for shade of glass appropriate for given welding or cutting operation available. Lens choice best made by equip. user. Working area should be screened or roped off to protect passersby from eye flashes. Skin burns prevented by coverings impervious to ultraviolet radiation. Arm guards, shirts, gauntlet gloves effectively protect from hot metal and tools. "Zinc-brass shakes" or "galvo" result from breathing large amts. of yellow-blue smoke from molten brass or galvanizing but no evidence of permanent injury from metal fume fever. Lead and cadmium poisoning from fine oxide particles breathed from fumes may produce chronic or permanent disability. Remove fumes by local exhaust or ventilation with 3" or 4" diam. exhaust hose or some type suction fan within 9" of weld. In difficult locations, welder should use approved respirator or air supplied mask.—*Ralph E. Noble.*

Welding of Lead. ROBERT DICK. Domestic Eng. **160:** 2: 42 (Aug. '42). Tin shortage makes plumbers' solder scarce. Lead jointing possible, however, without solder or reducing qual. of installation if done properly. Equip. and procedure detailed and liberally illustrated. —*Ralph E. Noble.*

Removal of Damaged Pipes. ANON. Wtr. and Wtr. Eng. (Br.) **44:** 132 (June '42). During air raids, pieces of metal often left in crater in position to obstruct repair of main. Adjacent pipes often split from end to end, rendering removal necessary before main could be repaired. Methods sought by which damaged pipes could be quickly broken into easily handled pieces. Use of explosives tried. In large no. of cases, removal of broken pipes greatly facilitated thereby. Expts. have shown that three 4-oz. charges placed equidistant on circumferential line generally sufficient for pipes of 1" thickness and over and should be placed at intervals of approx. 6'. 2- or 3-oz. charges suitable for thinner pipes. Charges should normally be placed on outside of pipe, but when large pieces of already broken pipe being broken into smaller fragments, small charges can be placed on inner surfaces. After charges fixed in position, they are covered with sandbags. Should always be air space of at least 12" between sand bags covering charges on pipe to be demolished and other pipes in close proximity.—*H. E. Babbitt.*

Solders With Less Tin for Wipes and Joints. ANON. Elec. World. **118:** 602 (Aug. 22, '42). Survey shows utilities exptg. with varying success in using solders with antimony, bismuth, silver and cadmium substituted for scarce tin. —*Ralph E. Noble*

Pointers on How to Conserve Equipment. *Expansion Joints* (*Slip Type*). W. A. SCHULMEISTER. Heatg. and Ventg. **39:** 6: 56 (June '42). *Installation.* Expansion joints must be installed so that slip aligned perfectly with pipe to prevent slip cramping and uneven packing wear. Guides should be used in long pipe runs to keep pipe in alignment. Best to anchor expansion joint or, if impractical, to anchor pipe adjacent thereto. Provide rigid and strong anchors in pipe line to direct movement of pipe to expansion joint. Avoid anchors which may become loose and permit pipe to slide. Every expansion joint installation should provide ample working room and access to packing glands. If pipe to be exposed to colder temps., move slip into joint enough to allow for max. contraction—otherwise all fittings and anchors may be subjected to excessive strain. Smooth slip essential to reduce wear on packing. Protect its surface during installation. *Maintenance.* Joints packed for steam service should not be subjected to hydrostatic test as packing will harden if water-satd. Choose packing most serviceable for particular fluid or gas; use good but not necessarily most expensive material. Expansion joints factory-packed under cold conditions. Most will compress on heating. Imperative, therefore, to draw up glands gradually and uniformly immediately after putting into service. Periodic inspection and adjustment for few days makes little attention necessary thereafter. Draw up glands uniformly to prevent binding and damaging slips. Insert feelers between gland and slip to det. whether clearance uniform all around. Packing resiliency destroyed by excessively drawing up gland at one time, forcing it into hard ineff. mass. Addnl. packing strand perhaps necessary after exposure to high temp. Slight oil leakage from stuffing box may come from packing and occur when first put into service. After initial adjustment, subsequent service reduced to periodic inspection and injection of lubricating compd. through fittings on joints to keep packing pliable and slip surface smooth. Further adjustments seldom necessary. Important to stop leaks through packing glands immediately. Permitted to continue, may cut channels through packing and slip, requiring replacement of both.—*Ralph E. Noble.*

Wood Pipe Can Also Serve. ROBERT TURNER. Military Engr. **34:** 266 (June '42). In typical 35,000-man cantonment, est. water system of wood stave pipe would save 9,193,000 lb. of iron and $222,140, based on '41 prices of class 150 bell and spigot c-i. pipe with calking materials, and of untreated wood pipe machine-banded for 250' head with g-i. wire and fitted with creosoted collars. Total cost of water system for such camp, $194,740 for wood pipe *vs.* $416,880 for c-i. Amt. of metal involved, 1,184,700

lb. *vs.* 10,378,300 lb. *Machine banded wood pipe* mfd. in random lengths to 20′, 2″ to 24″ id., spirally wrapped with heavy g-i. wire. Each joint, complete with coupling, finished piece of pipe ready for installation. Constr. procedure detailed. No bolts, gaskets or packing needed. *Continuous stave wood pipe* made from 6″ to 20′ id. and used mostly in sizes > 24″. Shipped knocked down, completely mfd., ready to assemble. Fitted with individual steel bands connected with malleable-iron pipe shoes. Joints connecting staves end to end made with g-i. steel tongues or malleable-iron butt-joints. *Armco emergency pipe* made of 100% non-critical materials requiring no steel bands, nails or metal reinforcing. Opening made of series of short, stout segments, given octagonal or other polygonal shape, connected in way to use full wood strength. Wood thickness variable with nominal pipe diam. Pipe has flexibility enabling build up side support and increasing load carrying capac. Units shop-assembled or fabricated in 12 or more lengths, simply joined in field. *Advantages:* Water delivered through wood pipe annually for less cost. Normally, will give excellent service 30 to 50 yr. without appreciable maint. expense. Initial outlay so low, initial saving more than covers replacement costs. Est. 15 to 25% greater flow through wood pipe. Delivers water with natural purity unchanged. [Unless treated chemically, will not wood harbor and support bact. infection much as leather washers, jute packing or wood rods in deep well hand-pumps?] Inside remains rust- scale- and tuberculation-free. Thus, capac. not reduced. Unaffected by frost, permits laying pipe in shallower ditches. Metal band broken at each joint precludes electrolysis. Soil acid-alk. conditions cause less trouble than with metal pipe. Due to its hygroscopic property, wood pipe kept full and under pressure, will remain in excellent condition indefinitely. Examples of ancient ship timbers cited. When impractical to keep pipe full and under pressure, as used for culverts, storm or san. sewers, or l-p. irrigation systems, desirable to fortify wood with preservative against fungi, insects, marine borers. Wood pipe successfully used in Helena, Mont., Vancouver and Chehalis, Wash., Beaverton and Monmouth, Ore., by Ore. State Game Com. and Mont. Pwr. Co.—*Ralph E. Noble.*

How to Repair Water Mains With Wood-Stave Collars. Leon H. Spaulding. Pac. Bldr. & Engr. **48: 7**: 38 (July '42). Broken c-i., steel, concrete or wood water mains effectively and quickly repaired with wood-stave collars. Place collar around pipe, then apply steel pipe bands to cinch it firmly and provide required strength to resist internal pressure. Stave must be long enough to span damaged pipe and sound pipe ends by several in. or ft. if necessary for desired stiffness. Gasket formed by wrapping several strands of cord or light rope around pipe under each end of staves. Electricians' rubber tape or common white clothes-line satisfactory. Applying wood collar successfully depends upon using proper no. of staves to circle for firm cinching and, at same time, provide sufficient wood to bring edges together firmly. Slight initial leakage between staves will take up as they swell when water returned to line. May rip stave to obtain right collar diam. Best to rip 2 pieces, thus having 2 edges without tongue and groove. Such plain edges form watertight joint if cut on proper bevel with slight emphasis on inside contact after planing or sanding to smoothness. External pipe surface must be smooth where rope gasket placed. Spanning hub end of c-i. or concrete pipe difficult. Temporary repair effective, however, by placing short filler collar of staves under each end of longer collar.—*Ralph E. Noble.*

Permeability and Absorption Properties of Bituminous Coatings. A. P. Anderson and K. A. Wright. Ind. Eng. Chem. **33:** 991 ('41). Discusses permeability of bituminous coatings to water vapor, oxygen and electrolytes. Mallison concluded from measurements of absorption of water by unfilled bituminous coatings that absorption proportional to content of ash in asphalt and negligible when content of ash less than 0.5%. Content of ash in most modern asphalts less than 0.5%. Absorption of

water by bitumens tested by detg. increase in weight of cubes of material after soaking in water for varying periods; by this test coal-tar pitches generally shown smaller increase in weight than petroleum asphalts. Test subject to error in that soluble substances may be lost from coal-tar pitch to water phase. Liquids permeate through bituminous coatings only if macroscopic defects, such as pinholes or cracks, present. Measurements of permeability of asphalts to water have shown: that permeability decreases as hardness of asphalt increases; that permeability of coal-tar pitch, which is denser material than asphalt, less on vol. basis than that of asphalts, but much same on weight basis; and that, using typical asphalt with opposite sides of asphalt exposed to water vapor with difference in vapor pressure between two sides equivalent to 15 mm. of mercury, amt. of water diffusing through 1 sq.cm. of asphalt 1 cm. thick would be 0.64 mg. per yr. and, if effective in causing rust, would consume only 1.3 mg. of iron 1 yr. Measurements of permeability of asphalt to oxygen, using cell divided by asphaltic membrane, one side of which in contact with oxygen, showed that permeability const. lower for unfilled air-blown asphalt than for filled air-blown asphalt contg. 28% soapstone talc, and that for all bituminous materials, permeability to oxygen lower than permeability to water vapor. Calcns. from results obtained from expts. using conductivity cell with asphalt diaphragm 0.5 mm. thick and a 0.1 *N* soln. of sulfuric acid showed that permeability of asphalt to hydrogen ions would be less than 7×10^{-12} g. per hr. per v. potential difference impressed across 1 sq.cm. of diaphragm 1 mm. thick.—*W.P.R.*

Lining Cast-Iron Pipe in Place. LEWIS H. SETON. Eng. News-Rec. **129:** 372 (Sept. 10, '42). In '40, decided to complete transmission main project begun in '31 with intention of acquiring c-i. pipe in instalments as funds became available. Section comprising 9,400′ of 36″ and 1,300′ of 42″ pipe had been laid when project initiated to avoid subsequent breaking of highway pavement being laid at time. When work resumed, reinforced-concrete pipe used for remainder of line to elim. excessive tuberculation which occurs in metal pipe, and decided to clean and line with cement mortar c-i. section which had been in ground 9 yr. but not used. Pipe cleaned at rate of about 1,000 lin.ft. per day by machine consisting of rapidly revolving shaft to which attached chains little longer than radius of pipe, small casting of wear-resisting steel being welded to end of each chain. Paint fumes and dust carried away from operator by draft of air created by blower. Mortar, consisting of 1:1 mixt. by wt. of std. portland cement and sand prepd. aboveground, using low water: cement ratio, and transported to lining machine in buggies inside pipe. Worm mechanism in machine forced mortar to rapidly revolving head that sprayed it against wall of pipe in advance of trowels which gave lining smooth, glass-like finish. Joints packed with dry mortar prior to lining operation. Condensation provided ample moisture for curing and line filled with water shortly after completion. Lining carried out at rate of 1,000 lin.ft. per day.—*R. E. Thompson.*

Vibration Periods of Structures. H. M. ENGLE. Eng. News-Rec. **128:** 859 (May 21, '42). Extensive studies by U.S. Coast & Geodetic Survey have made available comprehensive data on bldg. vibration characteristics. In most structures studied, measurements made with light or moderate winds acting, so amplitudes of vibration small. In some cases, vibration induced by eccentric revolving wheel of considerable mass. Vibration in no case sufficiently severe to break bond or friction between component parts of structure. Emphasized that before small period of vibration can be said to indicate high deg. of earthquake resistance, must be correlated with design and qual. of constr. Low period of 0.7 sec. or less, however, usually indicative of strength and rigidity, while large period, 1 sec. or more, usually indicates lack of bracing and lateral strength. Whether or not it may also indicate flexibility rather than lateral weakness debatable point. Tables presented showing representative figures for bldgs. of wide variety

of heights, sizes and shapes, bldgs. known to have been designed for lateral force and tall steel water tank towers. *Summary of conclusions drawn from data regarding water towers.* D. S. CARDER: Addnl. bracing effectively reduces period of tower, reduction increasing with amt. of bracing. Period of tower having loose tie rods reduced by tightening rods. Towers on yielding ground where piling required usually have greater periods than towers on firm ground. Author points out that further proof of effectiveness of bracing tall steel towers furnished in Imperial Valley, Calif., shock of May 18, '40. Of 8 tall towers, 2, one new, designed for lateral forces of 0.1 g., undamaged, while 2 of 6 wind-braced towers total collapses and other 4 badly damaged, with stretched or broken bracing rods.—*R. E. Thompson.*

Thawing Frozen Pipes by Electricity. L. A. FERNEY. Wtr. & Wtr. Eng. (Br.) **43:** 310 (Nov. '42). Method consists of connecting ends of frozen pipes to terminals of source of power which must be carefully regulated as to amperage and voltage. Generator or transformer with "dropping characteristic" necessary, so that when current drawn voltage drops. Many std. makes of arc-welding machines suitable for pipe thawing if they have output of at least 300 amp., open-circuit voltage not exceeding 60, are easily transported, are reasonably weatherproof, and have an ammeter built into or mounted on the machine. Transformer with condenser best proposition, but elec. authority may prefer motor-generators. Thawing current connection must give least possible resistance and must be made at nearest convenient points to frozen pipe section. Such points may be fire hydrants, street service cocks or exposed pipes in adjoining house. Continuity of circuit must be ensured. Several nonmetallic packing materials for making joints and well to know what used. Even if joint not complete, insulator resistance at that point may melt pipe, power consumption increased and thawing slowed. May become essential to bridge joints by copper strips or by making secondary connections at pipe joints. Grounded circuits, such as radio sets, etc., must be removed. Water meter in circuit must be removed or thawing be done in two stages, one before meter and one past meter. During thawing, cocks must be left open to prevent generation of steam. Thawing started, machine set for low amperage, which is gradually increased. If ammeter does not register, there are bad joints, bad connections, or grounding. Once reasonable current flow adjusted, it is left on for several minutes. If machine, or joints, or lead pipes get too hot, current must be reduced or periodically switched on and off. Following table based on thawing 100′ of pipe:

Diam. of pipe	*Amps. required*	*Minutes required*	*Kwhr. consumed*
$\frac{3}{4}$″	150	5	$\frac{1}{4}$
1″	200	8	$\frac{1}{2}$
2″	300	20	2
3″	400	60	8
6″	400	90	12

As rule of thumb, assuming reasonable connection cost, total cost approx. 1s. per in. of pipe diam. per 100′.—*H. E. Babbitt.*

Designs Cold Weather Water Level Gage. ANON. Elec. World **117:** 1521 (May 2, '42). Severe ice, snow conditions and occasional −40°F. temp. necessitated developing waterproof cyclometer type water level gage to register correctly under extreme exposure. Developed by A. E. Ebel of Wis.-Mich. Power Co. Actuating element, large, heavy counterweighted float moving up and down inside 14″ c-i. standpipe, riding on 4′ of transformer oil so water level in pipe remains below fp. Counterweight attached to float rides in 2″ pipe filled with kerosene and attached to side of larger pipe. Connecting metal tape passes over 12″ circum. pulley fastened to shaft on which 3 cylindrical register dials mounted. Twelve $\frac{1}{16}$″ diam. pins on pulley circum. engage holes in metal tape insuring pos. drive. Tape 0.003″ thick, $\frac{5}{8}$″ wide, with $\frac{5}{32}$″ diam. holes. Of 3 register dials (corresponding to tens, units and tenths of ft. travel by float) "tenths" or No. 1 dial fastened to main gage shaft while 2 others float on it. Double pinion, floating on separate shaft, meshes with large gears on adjacent "units" and "tenths"

register dials. No. of teeth in gears and pinions so selected that 1 full rev. of "tenths" dial advances "units" dial 1 position. Similar arrangement for others. All gears of $\frac{1}{4}''$ tempered "Masonite." Large gears, 11″ diams., 5″ pitch circle radius and 20 teeth. Small gears or pinions, 4″ diams., $1\frac{1}{2}''$ pitch circle radius and 6 teeth. Register dials, 11″ diam., $2\frac{1}{2}''$ wide, fastened to large gears and on downstream side of metal tape. Registering unit covered with 28″ x $21\frac{3}{8}''$ x 21″ of $\frac{1}{4}''$ "Masonite."—*Ralph E. Noble.*

A 36-Inch Water Main Crossing Under a Tidal Creek. ANON. Wtr. & Wtr. Eng. (Br.) **44:** 106 (May '42). Obstacle overcome crossing of tidal waterway with 36″ steel main in time limited to one tide. At low tide, channel depth varied from 3′ to 4′ and width was 124′. At high tide, max. depth 14′ and width 232′. Pipes at creek crossing $\frac{3}{8}''$ thick with 2″ thick flanges, with rubber joint, held together by $1\frac{1}{4}''$ bolts. Trench excavated in bed of creek, over which pipe floated and lowered into position. Length designed to sink by one operation limited to 170′, consisting of 5 straight pipes each 25′ long, with bend at each end 25′ and 20′ long resp., total weighing approx. $16\frac{1}{2}$ tons. During high tide, pipe lowered down inclined portion of slipway, movement being controlled by ropes. Time available between floating of pipe and onset of rapid fall of ebb tide approx. 4 hr. Essential that pipe be sunk into trench before rapid fall commenced. Pipe moved across creek by pivoting it on east end and swinging out west. At 12:20 P.M. pipe over prepared trench. At 2:46 P.M. whole of pipe had disappeared below water. Admission of water then stopped. Final sinking and positioning controlled by block and tackle secured to gantries. Whole brought to rest on bed at 3:20 P.M. Rapid flow of ebb commenced about same time. Filling over was carried out with excavating plant. Min. depth of cover $3\frac{1}{4}'$.—*H. E. Babbitt.*

Replacement of Pipeline at Mont Laurier, Quebec. RENE CYR. Eng. Cont. Rec. **55:** 15: 38 (Apr. 15, '42). Water supply of Mont Laurier derived from Lake Thibault, 2 mi. from town. Lake bounded almost entirely by wooded land. No residences located thereon, and town owns rights on most of lots and is acquiring the others. Pipe line (12″) to town and part of distr. system piping (6, 8 and 10″) consisted of wood stave pipe, installed in '13 which had reached limit of useful life and was causing considerable trouble. Accordingly, 12,000′ of 12″ c-i. pipe from lake to town and 4,500′ of 8–10″ distr. piping installed during winter of '41. Cost of excavating and laying pipeline and distr. mains \$0.75 and \$0.85 per lin.ft. resp. Estd. total cost \$85,000.—*R. E. Thompson.*

New Filtered-Water Reservoir at Windsor, Ont. J. CLARK KEITH. Can. Engr.—Wtr. & Sew. **80:** 5: 11 (May '42). Filtration plant serving Windsor and adjoining municipalities has rated capac. of 21 mgd. Demand of area during power interruptions must be met from storage as there is no standby pumping equip. Existing storage consists of 2-mil.gal. reservoir and 0.3-mil.gal. clear well, max. and min. available storage being 2.07 and 1.77 mil.gal., resp. Peak demand has now reached rate of 22.9 mgd. and min. storage thus provides less than 2 hr. supply. Power interruptions have been few, but on one occasion interruption exceeded 2 hr. Combination of these conditions would result in necessity for use of unfiltered water. Accordingly, new 2.3-mil.gal. reinforced-concrete reservoir has been constructed adjoining existing storage. New and old reservoirs will be operated in series normally but either may be used alone. Reservoir is 199 x 189′ and 11′ deep. All joints in walls are vertical and are of shelf type, each being provided with Cu tongue. Max. distance between joints is 50′ and no joints were permitted within 15′ of corners. Groove joints provided at junction of wall and floor slabs. Floor slab 8″ thick, with footings 10″ deeper and extending 12″ beyond walls. Roof slab 9″ thick and walls 12–15″ thick. Roof and 2′ earth cover supported by 85 columns. 6″ field-tile drain laid in clean gravel around entire structure ensures adequate drainage. Cost of land, reservoir, steel pipe and fencing was \$81,000. —*R. E. Thompson.*

Welded Water Reservoir Solves Demand Increase. ANON. Am. City **57:** 7: 58 (July '42). To meet unexpected increase in demand for water, brought about by suburban development, pop. increase and greater per capita use, Tulsa, Okla., completed arc-welded steel reservoir of 2½ mil. gal. capac. 8 vertical U-shaped ribs, 3′ sq. extend up the shell at equidistant points and continue over roof to form trusses. Ribs house overflow pipe, ladder and elec. cables. During peak demands, min. pressure of 20 psi. maintd. With normal requirement of 1 mgd., remainder reserved for fire protection.—*F. J. Maier.*

First Prestressed Gunite Water Tank for a Canadian Municipality. E. FANCOTT. Can. Engr.—Wtr. & Sew. **80:** 5: 17 (May '42). New elevated tank of 200,000 U.S. gal. capac. being constructed in Ste. Anne de Bellevue, Que., will be first structure of its kind to be erected in Canada. Tank will be domed cylinder with convex bottom, inside diam. of 38′ and height of 33′, and will be carried on supporting cylinder with height of 88.5′ and internal diam. of 35.5′. Overall height of tower will be about 120′. Prestressed method of constr. will enable dome to be 2″ thick and walls to have min. thickness of 4″. Preload system eliminates tendency to cracking which invariably occurs in ordinary reinforced concrete and which, although unimportant in most concrete work, results in leakage from and staining of tank structures. Preload tanks consist essentially of shell of gunite having compressive strength of 6,000–8,000 psi. Gunite maintd. in compression by high-tension steel rods, prestressed during constr.—*R. E. Thompson.*

Match Box Makes Handy Tape Holder. ANON. Heatg. & Ventg. **39:** 7: 32 (July '42). Difficult to hold eye end of tape line wearing gloves or mittens. Remove tray from penny match box. Cut down center and along bottom on one side of tray, letting cut portion hinge on end. Hook eye of line over this and put tray back in case or slide-box. This holds eye securely, firmly, at extreme corner, with tape end approx. flush with box edge. Box, itself, then affords excellent grip or holder no matter how heavily fingers protected. Can hold tape end squarely over any surface mark or against corners.—*Ralph E. Noble.*

War Production Board

Method of Making Application for Preference Ratings and Authority to Construct

ADMINISTRATIVE LETTER NO. 7—TO ALL UTILITIES

RECENT changes in orders, forms and procedures of the War Production Board necessitate a restatement of the requirements which must be met by a utility in making application for preference ratings and authority for the construction of additions to property and equipment.

A. Information Required in Support of Applications

1. *Extensions of Service*

The following information should be furnished in every case in which approval is requested for an extension of service (except where application is made on Form PD-545, as explained in paragraph B,1,b below):

(i) The producer's job number relating to the proposed construction

(ii) A description of the project or equipment to be served, including the location, an estimate of peak load and consumption, as well as other pertinent information

(iii) A description of the proposed utility construction, including a print of line construction showing size of conductor or pipe, capacity of transformers, pumps, compressors, tanks, holders and other equipment, the location of hydrants and important control valves, as well as other information relevant thereto

(iv) A statement of relationship to military needs, war production, public health or safety

(v) A copy of the customer's project or equipment preference rating order or certificate, if any (Such copies of orders or certificates are not required when utilities' applications accompany a customer's project application (see paragraph B,1,a below).)

(vi) A statement explaining whether service can be rendered in any other way, or by any other producer, with the use of smaller quantities of critical materials

(vii) An estimate of the total cost of producer's project

(viii) A list of materials required for the construction, with the estimated

cost, classified as indicated in the instructions for revised Form PD-200; an estimate of the weight of each construction material of the classes to be entered in Section D of such revised form. (Such list should indicate materials in inventory not to be replaced, materials to be purchased from the excess stocks of other utilities, materials to be obtained or replaced without priorities assistance and materials expected to be obtained or replaced with priorities assistance.)

2. *Additions and Expansions Other Than Extensions of Service*

Where an application involves additions to, and expansion of, plant other than extensions of service, the information supplied should include the following:

(i) The producer's job number relating to the proposed construction

(ii) The purpose and location of the project, accompanied by a sketch or diagram showing the relation of the project to existing facilities

(iii) A statement of the scope of the project, the population and customers to be served and the relation of the project to any existing or proposed construction

(iv) A statement, with supporting data, explaining the relation of the project to the war effort (A tabulation should be submitted showing volume, type and summary of major war loads.)

(v) A statement of the urgency of need for the proposed construction, including estimates of existing and scheduled dependable capacities (and of reserve and net assured capacities in the case of electric utilities) and requirements for the next three years (In case of water plant expansions, the immediate need therefor should be fully stated by reference to capacity, pressure, and quality, supported by summaries of operating records and, if a public health problem is involved, by a statement from the State Department of Health.)

(vi) If inter-connections with neighboring utility systems exist or are possible, a statement explaining the extent and capacity to which they are or could be utilized and the extent to which they could make available to others any capacity of applicant's system (If inter-connections exist and are not used, the statement should explain why.)

(vii) The latest practicable date of introduction of the project into commercial operation

(viii) An estimate of the total cost of the project

(ix) A list of materials required for the construction, with the estimated cost classified as indicated in the instructions for revised Form PD-200; an estimate of the weight of each construction material of the classes to be entered in Section D of such revised form. (Such list should indicate

materials in inventory not to be replaced, materials to be obtained or replaced without priorities assistance, materials to be purchased from excess stocks of other utilities and materials expected to be obtained or replaced with priorities assistance.)

B. Procedures for Filing Applications

1. *Extensions of Utility Service to Projects for Which a Rating Is Being Requested or to Projects Already Rated A-5 or Higher*

a. *Extensions to Projects Other Than Dwelling Construction*: Present War Production Board regulations require the builder of a project in this class to secure priorities assistance for the construction of his project by filing revised Form PD-200 (8–1–42). This form, which is prepared by the builder to whose project your services are to extend, requires him to secure from you an application to build necessary extensions of utility services and to attach your application to his when it is filed.

You should prepare such an application in the form of a letter requesting approval and supplying the information specified in paragraph A,1 of this letter. This procedure will result in the approval of utility service extensions to new projects concurrently with approval of the project. The same rating or ratings will be assigned to the utility extensions as are assigned to the project. When the project application is approved, a letter approving the service extension will be sent to the utility.

We particularly wish to call your attention to the fact that Form PD-545 should not be used for the type of application here being discussed. Form PD-545 is applicable only to extensions to serve dwelling units (see paragraph B,1,b below).

If an extension of service is needed to serve a project or equipment which has already been rated A-5 or higher, and no rating has yet been granted for the extension, an application for its approval should be made in letter form requesting approval and supplying the information specified in paragraph A,1 of this letter. Such applications should be mailed to the Power Branch, War Production Board, Washington, D.C. Ref: P-46.

b. *Extensions to Serve Dwellings*: Applications for the approval of such extensions should be made on Form PD-545, prepared in quadruplicate, regardless of whether (1) the dwelling construction has been assigned a preference rating, (2) application is concurrently therewith being made for a rating, or (3) application for authority to begin construction under Order L-41 is being made. PD-545 application forms should be used in connection with PD-105, PD-200 and PD-406 applications for housing construction. The procedures to be followed in using Form PD-545 have been fully explained in our letters of June 23 and August 25 and in Administrative Letter No. 6.

2. Extensions of Service to Projects Rated Lower Than A-5 or to Nonrated Projects (Whether Dwelling Construction or Other); Miscellaneous Additions to, or Expansion of, Plant

In cases involving extensions to projects rated lower than A-5, to projects for which no rating has been or will be requested, and other additions to or expansion of utility property or equipment in excess of those permitted by P-46, without specific authorization, applications should be made as stated below. In general, such construction will not be authorized unless required for military needs, war production, public health or safety.

a. If all of the materials required are in inventory in excess of a practical working minimum or can be acquired without the use of a preference rating, application under P-46 for approval to withdraw such materials should be made by letter.

b. If a preference rating is required to obtain or replace any or all of the materials needed, application should be made on Form PD-1A or Form PD-200. Form PD-1A should be used only (1) where the construction applied for is an extension with a total dollar value of materials (including items for which no preference rating is required) of $2,500 or less, or (2) where not more than five items of material or equipment (including items for which no preference rating is required) are needed for the addition or expansion. In all other cases within the scope of this paragraph the Form PD-200 should be used and a supplementary statement attached embodying information specified in paragraph A,2 of this letter, to the extent that such information is not required in Form PD-200.

The issuance of a project rating (P-19h Order) or a PD-1A rating constitutes authority to use only the materials listed in the application. Such a rating does not constitute authority to construct an entire job or project unless the total quantity of material for the job or project is specified in the application.

3. Application for Higher Ratings in Connection With Projects Previously Approved

Where it is necessary to obtain higher ratings for particular items involved in construction, for which a rating was originally assigned in the P-19 series, application should not be made on Form PD-1A or Form PD-200. Such applications must be handled as amendments of the original project and should be made on Form PD-200B. In preparing such applications you should, as far as possible, consolidate in one application all the items of a project on which improved ratings are required, so that the entire matter can be considered at one time. However, requests for higher ratings should be made only where it has been definitely determined

that an improved rating will be necessary to obtain delivery of the materials in time to meet the construction schedule.

4. *Application for Higher Ratings or for Relief From Restrictions of P-46 When Only Maintenance, Repair or Operating Supplies Are Involved*

The acquisition and use of materials as maintenance, repair and operating supplies and for minor additions and improvements permitted by P-46 without specific authorization will continue for the fourth quarter of 1942. Where the restrictions of the order or the preference ratings provided do not enable the acquisition of material needed for these purposes, applications for relief may be made in the following manner:

a. Whenever, in order to maintain minimum operations standards, it is necessary to acquire material or use material already on hand for maintenance, repair and operating supplies and for minor additions and improvements as defined in the order, and such acquisition or use would exceed the restrictions in paragraph (f) [of P-46], the producer should make application by letter or telegram setting forth the reasons why it is necessary to exceed the restrictions.

b. Whenever material is required for maintenance, repair and operation supplies and for minor additions and improvements, and such material cannot be obtained on the ratings provided in the order either from suppliers or from other utilities, application for a higher rating may be made on Form PD-1A. It is essential that no application be filed on Form PD-1A for material which is entitled to a rating under P-46 until all practical possibilities have been explored for obtaining the material on the ratings provided by P-46. Assignment of a rating higher than provided by P-46 does not constitute authorization to exceed the delivery or withdrawal restrictions contained in paragraph (f) of the Order.

5. *Preference Ratings for Emergency Repairs*

If the ratings assigned by P-46 are not adequate to secure materials for emergency repairs, or if the producer is prevented from applying the emergency repair rating of the order because of the limitations on use of this rating, application for an emergency rating to secure materials to repair breakdowns of producers' facilities may be made by telegram. Such applications should be addressed to the Power Branch, War Production Board, Washington, D.C., Ref: P-46, and should contain the following information:

(i) The date and a description of the breakdown

(ii) A description of the emergency, including war production curtailments that are resulting therefrom or impairment of public health or safety

(iii) The applicant's purchase order number

(iv) The name and address of supplier

(v) The rating required by supplier to make delivery in time to meet emergency

(vi) A description of the materials required

(vii) Estimated weight of copper, steel or alloy

(viii) Estimated value of materials.

Applications for materials to repair equipment where the services are being adequately rendered by spare equipment or from other sources are not considered emergencies and should be filed on form PD-1A.

C. General Instructions

We wish to emphasize that the assignment of a preference rating to any construction does not authorize replacement of material taken from inventory except to the extent that the applicant's inventory is less than a practical working minimum as defined in Preference Rating Order P-46.

In every case, before applications are filed, you should determine to what extent the materials to be obtained or replaced are available by purchase from excess stocks of other utilities. The amounts which can be thus purchased should be clearly noted in the application.

Any communication with reference to P-46 as amended should be addressed to the Power Branch, War Production Board, Washington, D.C. Ref: P-46.

(signed)
HERBERT S. MARKS
Acting Chief, Power Branch

October 9, 1942

TITLE 32—NATIONAL DEFENSE

Chapter IX—War Production Board

Subchapter B—Division of Industry Operations

Part 978—Utilities Maintenance, Repair and Supplies

PREFERENCE RATING ORDER P-46 AS AMENDED OCTOBER 10, 1942

Note: Those paragraphs and phrases (except headings) printed in italics comprise the changes in the Order.

Preference Rating Order P-46, as heretofore amended, is hereby amended to read as follows:

978.1—Preference Rating Order P-46

(a) *Definitions for the Purposes of This Order:*

(1) "Producer" means any individual, partnership, association, corporation, governmental corporation or agency, or any organized group of persons, whether incorporated or not, located in the United States, its territories or possessions, or any such producer located in the Dominion of Canada, to whom and in whose name, a copy of this order has been specifically issued, engaged in, or constructing facilities for the purpose of engaging in, one or more of the following services, whether or not such producer has applied the preference ratings herein assigned:

(i) Supplying electric power directly or indirectly for general use by the public.

(ii) Supplying gas, natural or manufactured, directly or indirectly for general use by the public.

(iii) Supplying water directly or indirectly for general use by the public.

(iv) Supplying central steam heating directly or indirectly for general use by the public.

(v) Supplying public sanitation services, but not including manufacturers of public sanitation products.

(2) "Material" means any commodity, equipment, accessory, part, assembly, or product of any kind.

(3) "Maintenance" means the upkeep of a Producer's property and equipment in sound working condition.

(4) "Repair" means the restoration of a Producer's property and equipment to sound working condition after wear and tear, damage, destruction of parts, or the like have made such property or equipment unfit or unsafe for service.

(5) "Operating Supplies" means:

(i) Material which is essential to the operation of any of the industries or services specified above and which is generally carried in a Producer's inventory and charged to operating expense accounts.

(ii) Material for an addition to or an expansion of property or equipment provided that such addition or expansion shall not include any work order, job or project in which the cost of Material shall exceed $1,500 in the case of underground construction and $500 in the case of other construction and provided further that no single construction project shall be subdivided into parts in order to come below these limits.

(6) Material for "Operating Supplies," "Maintenance," and "Repair" includes only Material which is essential to minimum service standards and does not include Material for the improvement of a Producer's property or equipment through the replacement of Material which is still usable in the existing installation with Material of a better kind, quality, or design.

(7) "Supplier" means any person with whom a purchase order or contract has been placed for delivery of Material to a Producer or to another Supplier.

(8) "Calendar Quarterly Period" means the quarterly period commencing on the first day of the first, fourth, seventh, and tenth months of the calendar year and ending, respectively, on the last day of the third, sixth, ninth, and twelfth months of the calendar year, or the Producer's customary accounting period closest to such period.

(9) *"Inventory" means all new or salvaged material in the producer's possession, unless physically incorporated in plant, without regard to its accounting classification, excluding, however, appliances and merchandising supplies, and material in the producer's possession which is segregated for use in additions and expansions specifically authorized under paragraph (e)(2) of this order, or by an operative order in the P-19 series, or by an operative preference rating certificate issued by the War Production Board.*

(b) *Assignment of Preference Ratings*

Subject to the terms of this order the following preference ratings are hereby assigned:

(1) *Producers*

(i) AA-5 to deliveries, to a Producer, of Material required by him for the maintenance or repair, and to deliveries of operating supplies.

(ii) Subject to the provisions of paragraph (e)(2), AA-5 to deliveries, to a Producer, of Material required by him for protection against sabotage, air raids, or other hostile acts, provided such protection is directed by an authorized federal or state agency.

(iii) Subject to the provisions of paragraph (e)(2), deliveries, to a Producer, of Material required by him for the construction of transmission, switching and distribution facilities necessary to serve projects bearing a rating of A-5 or better, or to serve equipment the delivery of which is rated A-5 or better, are assigned the same rating as is assigned to such project or to the delivery of such equipment; except that where such project or such equipment is assigned two or more ratings and both or all of these are A-5 or better, deliveries to a Producer *of items containing copper, or iron, or steel are assigned the highest rating which is assigned by the project or equipment rating order to deliveries of items containing the like metal, and in the case of all other items, such deliveries to a producer are assigned the lowest rating which is assigned to such project or equipment.*

(*iv*) *AA-2X* to deliveries, to a producer, of material required by him for repair of facilities following an actual breakdown thereof, or to make reasonable advance provision for such repair, provided that such *AA-2X* rating shall not be applied to more than 30 per cent of the material in any class which *can be* scheduled for delivery in each calendar quarterly period under the provisions of paragraph (f) of this order.

(c) *Revocation or Amendment.* This Order may be revoked or amended at any time as to any Producer or any Supplier. In the event of revocation, deliveries already rated pursuant to this Order shall be completed in accordance with said rating, unless the rating has been specifically revoked with respect thereto. No additional applications of the rating to any other deliveries shall thereafter be made by the Producer or Supplier affected by such revocation.

(d) *Restrictions on Use of Rating.* The preference ratings hereby assigned shall not be applied or extended by a Producer or Supplier to obtain deliveries of scarce Material, the use of which could be

eliminated without serious loss of efficiency by substitution of a less scarce Material or by change of design.

(e) *Application and Extension of Ratings*

(*1*) *The ratings assigned by this order may be applied and extended by a producer or supplier, either:*

(*i*) *In accordance with Priorities Regulation No. 3 as amended; provided, however, that in no case may the ratings assigned in paragraphs (b)(1)(ii) and (b)(1)(iii) hereof be applied or extended until approval has been granted pursuant to paragraph (e)(2) hereof, or*

(*ii*) *By endorsement of the following statement on the original and all copies of each purchase order or contract for material the delivery of which is rated by this order, and delivery of a copy of such order or contract to any supplier:*

> Rating ————. Material to be delivered pursuant to paragraph (b) ———— of Preference Rating Order P-46, Utilities Maintenance, Repair, and Supplies, with the terms of which I am familiar.
>
> ______________________________
> *(Name of Producer or Supplier)*
>
> ______________________________
> *(Signature of Designated Official)*

(2) In addition to the requirements of paragraph (e)(1), a producer in order to apply the preference rating assigned by paragraphs (b)(1)(ii), and (b)(1)(iii), *to segregate material from inventory for the uses described in such paragraphs, or to accept delivery of material for such uses*, must, unless otherwise directed, communicate with the Power Branch, War Production Board, Washington, D.C., Ref: P-46, (*except that communications with reference to public sanitation shall be addressed to the Bureau of Governmental Requirements, War Production Board, Ref: P-46*), supplying in detail the following information or such other information as may from time to time be required.

(*i*) *The producer's job number relating to the proposed construction.*

(*ii*) *A description of the project or equipment to be served, including the location, an estimate of peak load and consumption, as well as other pertinent information.*

(*iii*) A description of the proposed utility construction, including a print of line construction, showing size of *conductor* or pipe, capacity of transformers, *pumps, compressors, tanks, holders, and other equipment, the location of hydrants and important control valves*, as well as other information relevant thereto.

(*iv*) A statement of relationship to military needs, war production, public health or safety.

(*v*) A copy of the customer's *project or equipment* preference rating order or certificate. (*Such copies of orders or certificates are not required when utilities' applications accompany the customer's project application.*)

(*vi*) A statement explaining whether service can be rendered in any other way or by any other producer, with the use of smaller quantities of critical materials.

(*vii*) *An estimate of* the total cost of the producer's project.

(*viii*) A list of materials required for the construction, *giving the estimated weight of each material with the estimated cost, classified as indicated in the instructions for revised Form PD-200.* (*Such list should indicate materials in inventory not to be replaced, materials to be purchased from the excess stocks of other utilities, materials to be obtained or replaced without priorities assistance, and materials expected to be obtained or replaced with priorities assistance.*)

The *Director General for Operations* will notify the Producer whether and to what extent the application is approved *and no producer shall apply such preference ratings, segregate material from inventory for the uses described in paragraphs* (*b*)(*1*)(*ii*) *and* (*b*)(*1*)(*iii*), *or accept delivery of material for such uses without such approval.*

(3) In addition to the records required to be kept under Priorities Regulation No. 1, the Producer, and each Supplier placing or receiving any purchase order or contract rated hereunder, shall retain, for a period of two years, for inspection by representatives of the War Production Board, endorsed copies of all such purchase orders or contracts, whether accepted or rejected, segregated from all other purchase orders or contracts or filed in such manner that they can be readily segregated for such inspection.

(f) *Restrictions on Deliveries, Withdrawals, and Inventory.*

(1) No Producer shall, in placing orders, schedule for delivery to him in any calendar quarterly period any items of Material (whether or not rated pursuant to this Order) to be used as Operating Supplies or for Maintenance or Repair or for any other purpose (*except material to be segregated for use in additions and expansions specifically authorized under paragraph* (*e*)(*2*) *of this order, or by an operative order in the P-19 series, or by an operative preference rating certificate issued by the War Production Board*), the aggregate dollar volume of which shall exceed the applicable percentage, as indicated below, of the aggregate dollar volume of withdrawals of items of materials of the same class from inventory during the calendar year 1940. *Such percentage shall be:*

(*i*) *In the case of electric power producers*

(*a*) *15 per cent as to transmission and distribution material, provided that not less than 75 per cent of all scheduled deliveries of wire, cable, and bus bar shall be from the inventory of another producer;*

(*b*) *25 per cent as to all other classes of material;*

(*ii*) *In the case of gas and water producers*

(*a*) *15 per cent as to transmission and distribution material, provided that not less than 40 per cent of all scheduled deliveries of such material (excluding meters) shall be from the inventory of another producer;*

(*b*) *25 per cent as to all other classes of material;*

(*iii*) *In the case of central steam heating and sanitation service producers, 25 per cent as to all classes of material.*

(2) No Producer shall at any time accept deliveries (whether or not rated pursuant to this Order) of any item of Material to be used as Operating Supplies or for Maintenance or Repair or for any other purpose (*except material to be segregated for use in additions and expansions specifically authorized under paragraph (e)(2) of this order, or by an operative order in the P-19 series, or by an operative preference rating certificate issued by the War Production Board*) until Producer's inventory of items of the same class has been reduced to a practical working minimum. Such inventory shall in no case exceed:

(*i*) *For any class of material commonly used for transmission and distribution plant (including meters, and in the case of electric systems, material for switching and substation plant as well as wire, cable, and bus bar material) 60 per cent of the aggregate dollar volume of items of material of the same class in inventory on the most recent date during the calendar year 1940 on which the producer's inventory was taken;*

(*ii*) *For every other class of material,* the aggregate dollar volume of items of material of the same class in inventory on the most recent date during the calendar year 1940 on which the producer's inventory was taken.

(3) No Producer shall

(i) during any Calendar Quarterly Period, make withdrawals from inventory of any item of Material to be used as operating supplies for Maintenance or Repair or for any other purpose (*except to segregate such material for use in additions and expansions specifically authorized under paragraph (e)(2) of this order, or by an operative order in the P-19 series, or by an operative preference rating certificate issued by the War Production Board*), the aggregate dollar volume of which shall exceed:

(*a*) *For any class of material commonly used for transmission and distribution plant (including meters and, in the case of electric systems, material for switching and substation plant as well as wire, cable, and bus bar material), 60 per cent of the aggregate dollar volume of withdrawals of such items of material of the same class during the corresponding quarter of 1940, or at the producer's option, 15 per cent of the aggregate dollar volume of withdrawals of such items of material of the same class during the calendar year 1940;*

(*b*) *For every other class of material*, the aggregate dollar volume of withdrawals of such items of material of the same class during the corresponding quarter of 1940, or at the producer's option, 25 per cent of the aggregate dollar volume of withdrawals of such items of material of the same class during the calendar year 1940.

(*ii*) *Construct an addition to or an expansion of property or equipment, and no producer shall, in the case of contract construction, accept delivery of material for such purposes unless:*

(*a*) *Such addition or expansion is specifically authorized by the Director General for Operations, or*

(*b*) Such addition or expansion is an extension less than 250 ft. in length (*including service drop or service pipe and any portion built by or for a consumer*) of a line to serve a new building where the foundation, under the main part of the structure, was completed prior to July 1, 1942, or

(*c*) Such addition or expansion is not an extension of a line to consumer premises and requires an expenditure of material having a dollar value of less than $1,500 in the case of underground construction and $500 in the case of other construction: *Provided, however*, That no single work order, job, or project shall be subdivided into parts to come below these limits.

(4) Notwithstanding the provisions contained in paragraphs (f) (1) (2) and (3), a Producer may:

(i) In any Calendar Quarterly Period increase the aggregate dollar volume of scheduled deliveries of Material for the Maintenance and Repair of, and for Operating Supplies, for, generation, production, and pumping facilities, and withdrawals of Material for such use over the limits prescribed in paragraphs (f) (1) and (f) (3) respectively proportionately to the increase in system output in the preceding Calendar Quarterly Period over the system output in the calendar quarter of 1940 corresponding to such preceding Calendar Quarterly Period;

(ii) Schedule for delivery in any Calendar Quarterly Period items of Material which will increase the aggregate dollar volume of

inventory of Material for the Maintenance and Repair of, and for Operating Supplies for, generation, production and pumping facilities over the aggregate dollar volume of Material in inventory on the most recent date during the calendar year 1940 on which the Producer's inventory was taken, proportionately to the increase in system output during the preceding Calendar Quarterly Period of 1940 corresponding to such preceding Calendar Quarterly Period;

(iii) Schedule for delivery to him in any Calendar Quarterly Period consumers' meters and house-regulators or make withdrawals from inventory of such meters and house-regulators in an amount not in excess of *15* per cent of the number of such meters or house-regulators condemned and destroyed by the Producer in 1940, (or, at the Producer's option, not in excess *of 60 per cent* of the number of such meters and house-regulators condemned and destroyed in the corresponding quarter of 1940) plus the number of meters and house-regulators necessary to serve the net increase in customers occurring in the current quarter. For the purposes of this subparagraph (iii), withdrawals of meters and house-regulators shall not include meters or house-regulators put in service to replace meters and house-regulators removed from service;

(iv) In order to provide Material for unavoidable and emergency situations in cases where the inventory of a class of Material exceeds a practical working minimum, accept in any Calendar Quarterly Period deliveries of any short item of Material within such class, such deliveries, however, not to exceed 5 per cent of the dollar volume of withdrawals of Material of the same class in the calendar year 1940;

(v) In any Calendar Quarterly Period, schedule for delivery or accept delivery of, or make withdrawals in such period of, Material necessary for the Maintenance or Repair of the Producer's property or equipment which is damaged by acts of the public enemy, sabotage, explosion, fire, flood or other climatic conditions: *Provided*, That if the restrictions in paragraph (f) (1) (2) or (3) as modified by the provisions of paragraph (f) (4) (i) (ii) (iii) and (iv) are exceeded because of the scheduling or acceptance of such deliveries, or because of such withdrawals, a full report thereof together with reasons therefor shall be made immediately to the *Director General for Operations.*

(vi) In any calendar quarterly period schedule for delivery, or accept delivery of, items of material in any class (as such class is indicated

in War Production Board inventory report forms) having in the aggregate a dollar value not more than the dollar value of material of the same class taken from the producer's inventory for delivery to other producers or suppliers, and of such material so taken for delivery to any person pursuant to Priorities Regulation No. 13, and of such material taken for delivery to any person to whom a special sale of war material would be permissible under paragraphs (c)(2)(i) and (c)(2)(iv) of Priorities Regulation No. 13, to the extent that such takings have reduced the producer's inventory of items of material of the same class below a practical working minimum which shall in no case exceed the limits set up in paragraph (f)(2) hereof; and

(vii) In any calendar quarterly period withdraw from inventory items of material in any class (as such class is indicated in War Production Board inventory report forms) having in the aggregate a dollar value not more than the dollar value of usable material of the same class salvaged from plant during the current calendar quarterly period.

(5) The *Director General for Operations* may, on the application of any Producer, authorize such Producer to exceed the restrictions on deliveries, withdrawals, and inventory set forth in this paragraph (f). Nothing herein contained shall be construed to affect in any way any specific authorizations or approvals issued by the *Director General for Operations* pursuant to Preference Rating Order P-46 prior to *October 10, 1942.*

(6) The provisions of paragraphs (f)(1), (f)(2) and (f)(3)(i) shall not apply to fuel, water purification chemicals, wooden poles or wooden crossarms.

(g) Sales of Material From Excess Inventory. Any producer may sell to any other producer material from the seller's inventory in excess of a practical working minimum, provided that

(1) A preference rating of A-1-j or higher assigned by this order or by any preference rating certificate or order, or

(2) A specific direction issued by the Director General for Operations is applied or extended to the producer selling such material; and any such sale shall be expressly permitted within the terms of paragraph (c)(3) of Priorities Regulation No. 13.

(h) *Audits and Reports.*

(1) Each Producer and each Supplier who applies the preference ratings hereby assigned, and each person who accepts a purchase order or contract for Material to which a preference rating is applied, shall submit from time to time to an audit and inspection by duly authorized representatives of the War Production Board.

(2) Each Producer and each such Supplier shall execute and file with the War Production Board such reports and questionnaires as said Board shall from time to time request. No such reports shall be filed until such time as the proper forms are prescribed by the War Production Board.

(3) Each Producer shall maintain a continuing record of inventory and of segregated Material in his possession.

(i) *Communications to War Production Board.* All reports required to be filed hereunder and all communications concerning this Order (*except reports and communications with reference to public sanitation, which must be addressed to the Bureau of Governmental Requirements, War Production Board, Ref: P-46*), shall, unless otherwise directed, be addressed to: *Power Branch*, War Production Board, Washington, D.C. Ref: P-46.

(j) *Violations.* Any Person who wilfully violates any provision of this Order or who, *in connection with this order, wilfully conceals a material fact or furnishes false information to any department or agency of the United States, is guilty of a crime, and upon conviction may be punished by fine or imprisonment. In addition, any such person may be prohibited from making or obtaining further deliveries of, or from process or use of, material under priority control, and may be deprived of priorities assistance.*

(k) *Applicability of Priorities Regulations.* This Order and all transactions affected thereby are subject to all applicable provisions of the priorities regulations of the War Production Board as amended from time to time.

(P.D. Reg. 1, as amended, 6 F.R. 6680; W.P.B. Reg. 1, 7 F.R. 561; E.O. 9024, 7 F.R. 329; E.O. 9040, 7 F.R. 527; E.O. 9125, 7 F.R. 2719; sec. 2(a), Pub. Law 671, 76th Cong., as amended by Pub. Laws 89 and 507, 77th Cong.)

Issued this 10th day of October, 1942.

(signed)
ERNEST KANZLER
Director General for Operations

SUPPLEMENTARY PREFERENCE RATING ORDER P-46-a AS AMENDED OCTOBER 10, 1942

In accordance with the provisions of Sec. 978.1 *Preference Rating Order P-46*, as amended, which the following order supplements:

978.2—Supplementary Preference Rating Order P-46-a

Notwithstanding the provisions of paragraph (f)(3)(ii) of Preference Rating Order P-46 as amended, service connections may be made by producers to facilities of the Army or Navy of the United States or the Maritime Commission, upon the direct order of the Army, Navy, or Maritime Commission: *Provided*, That the total length of the main extension or the service line does not exceed 250 ft., and the total cost of materials required for the extension does not exceed $1,500 in the case of underground construction and $500 in the case of other jobs.

(P.D. Reg. 1, as amended, 6 F.R. 6680; W.P.B. Reg. 1, 7 F.R. 561; E.O. 9024, 7 F.R. 329; E.O. 9040, 7 F.R. 527; E.O. 9125, 7 F.R. 2719; sec. 2(a), Pub. Law 671, 76th Cong., as amended by Pub. Laws 89 and 507, 77th Cong.)

Issued this 10th day of October, 1942.

(signed)
ERNEST KANZLER
Director General for Operations

EDITOR'S NOTE: *See page 1 of News of the Field in this issue of the* JOURNAL *for interpretations of and additional information on Order P-46.*

War Manpower Developments

Regulation of Enlistment of Men in Federal Posts and War Industry

A JOINT Army-Navy policy regulating the enlisting or commissioning of civilians employed in Federal agencies and specified war industries has been adopted by the Secretary of War and the Secretary of the Navy, on recommendation of the Joint Army and Navy Personnel Board. [Statement released September 11, 1942.]

Civilians occupying key positions in Federal agencies and in a list of other occupations in war industry will not be accepted for commission or enlistment without first obtaining a written release from the head of the agency or war industry concerned. These key civilians include: executives; heads of major divisions or departments and principle sub-divisions; and technical experts whose principal duties involve design, planning or research.

In the case of civilian employees of Federal agencies and the listed war industries whose jobs are outside these executive and technical-expert categories, a release from the local Selective Service board will be required before acceptance for enlistment or commission, if the applicant is a Selective Service registrant. If a disagreement occurs between the local board and the industry concerned, appeal may be taken under Selective Service regulations. If the applicant in this group is not a classified Selective Service registrant, decision as to whether he may be accepted for commission or enlistment without a release from the head of the agency or war industry will depend upon the merits of the individual case. In the event of disapproval by the head of the agency or industry, the final decision will rest with a committee appointed by the Joint Army and Navy Personnel Board.

Another basic policy set forth in the joint statement is that, except in furtherance of definite mobilization plans, no personnel other than students in recognized institutions will be commissioned or enlisted and then be permitted to remain on an inactive status, keeping their civilian employment.

The list of essential activities which was issued in connection with the statement of policy on the enlisting and commissioning of civilians was prepared by the United States Employment Service, pursuant to the first directive issued by the War Manpower Commission, and after consultation

with representatives of the War Production Board, the Department of Agriculture and other departments and agencies, as well as the War Department and the Navy Department.

The list is also to be used as a guide by the local Selective Service boards in connection with problems of occupational deferment, and by the United States Employment Service in determining which types of activities should be regarded as having prior claim to the workers available for referral to job openings. The War and Navy Department policies on the appointment and commissioning of civilians will apply to any revisions of this list that may be approved by the War Manpower Commission or the Selective Service System.

The governmental services included in the list are defined as those necessary for the maintenance of health, safety, and morale, and the prosecution of the war. The other activities listed as essential are given in detail under the following heads:

Production of Aircraft and Parts
Production of Ships, Boats and Parts
Production of Ordnance and Accessories
Production of Ammunition
Agriculture
Food Processing
Forestry, Logging and Lumbering
Construction
Coal Mining
Metal Mining
Nonmetallic Mining and Processing and Quarrying
Smelting, Refining and Rolling of Metals
Production of Metal Shapes and Forgings
Finishing of Metal Products
Production of Industrial and Agricultural Equipment
Production of Machinery
Production of Chemicals and Allied Products
Production of Rubber Products
Production of Leather Products
Production of Textiles
Production of Apparel
Production of Stone, Clay and Glass Products
Production of Petroleum, Natural-Gas and Petroleum and Coal Products
Production of Finished Lumber Products
Production of Transportation Equipment
Transportation Services
Production of Materials for Packing and Shipping Products
Production of Communication Equipment

Communication Services
Heating, Power and Illuminating Services
Repair and Hand Trade Services
Health and Welfare Services, Facilities and Equipment
Educational Services
Governmental Services

In this list, water supply and sewerage systems, as well as fire and police protection and public health services are specifically included under the head, Health and Welfare Services, Facilities and Equipment. Electric light, power and gas utilities and steam-heating companies, on the other hand, are considered separately under the head, Heating, Power and Illuminating Services. Highway and street construction and repair is included under the head, Construction, and public and private vocational training, under Educational Services.

Wartime Revision of Water Service Regulation

Illinois Commerce Commission Order

On September 25, 1942, the Illinois Water Service Company filed with the Illinois Commerce Commission an addition to its "Rules, Regulations and Conditions of Service," to cover its operations in Champaign, Urbana and Pontiac, Ill., for the duration of the war emergency. The commission approved the measure on October 7, making it effective as of 30 days after the filing date. The text of the addition was as follows:

XII. National Emergency Conditions

68. The obligations of the Company to supply service and the obligations of the Company under this schedule and under General Orders of the Illinois Commerce Commission are, during the present war emergency, and subject always to review of the Illinois Commerce Commision, contingent upon:

(a) The availability to the Company of such labor, equipment, materials and facilities as may be necessary for the rendition of service.

(b) The availability of capacity necessary to supply the service.

(c) Existing and future orders of the federal government or other authority pertaining to the purchase, replacement or use of equipment and materials, the supply of service for defense or non-defense operations or any other subject affecting the Company in its operations.

This regulation, made available for publication by Frank C. Amsbary Jr., Vice-Pres., Illinois Water Service Co., is not only unusual, but is an example of foresighted planning for the eventualities of the present emergency.

Wartime Protection of Water Supply Quality

DURING the Chicago Conference of the A.W.W.A., the members of the Water Purification Division requested that a special committee, consisting of President Abel Wolman, Water Purification Division Chairman Marsden C. Smith and Secretary Harry E. Jordan, prepare a statement concerning wartime protection of water supply quality. After an extended review of the subject and consultation with the Federal Bureau of Investigation, a statement, the text of which is given below, was prepared.

It will be noted that the statement refers to the action taken by the Board of Directors in January 1942 in reference to "Protection of Water Plants" and "Chlorination of Water." These statements were published in the March 1942 JOURNAL and the Directors of the Association have not modified either one of them in any detail. The following statement on "Wartime Protection of the Quality of Public Water Supplies" has been approved by the Board of Directors of the A.W.W.A.

While there is no evidence that sabotage of any public water supply has been attempted or effected during the current or the last world war, good judgment leads to the attitude that certain special protective measures are fully justified.

The Board of Directors of the American Water Works Association, early in 1942, stated certain broad policies covering "Protection of Water Plants" and "Chlorination of Water." These statements were published in the March 1942 JOURNAL (p. 468). Their validity continues.

Those persons who are in responsible charge of water purification and distribution may properly put into effect the following control and protective measures:

1. Coastal cities, cities where war production industry centers and cities where military activity centers may properly consider themselves more greatly exposed to dangers of sabotage than those not so situated. Water department executives should obtain from responsible state or regional authorities advice whether a city and its water supply are in the primary or secondary category so far as defense measures are concerned.

2. Routines established for the protection of the quality of public water supply should be intelligently related to the all-over protection of the water

supply system. These routines should not increase the number of technical employees disproportionately at the time when all skilled personnel is greatly needed and must be employed where the services are rendered upon activities of the highest possible value in the war effort.

3. Such points of sampling the supply, both in production and distribution, shall be established as will afford clear evidence of the quality of the water as it is delivered to significant numbers of the customers served.

4. Routines of examination of samples should include such tests as chlorine consumed, chlorine residual, oxygen consumed, alkalinity, hydrogen ion concentration and total bacteria, each of which, upon a repetitive basis, will disclose deviations in water quality if significant change occurs. The above list does not include all possible tests that might be made. The person responsible for such studies is expected to require any test that, in his judgment, has significance proportionate to the energy and time spent in making it.

5. Since these regularly collected samples will disclose a pattern associated with each determination and since the significance of deviation in any such test has been published and is available to responsible water works men, unaccounted-for change must be the signal for caution and for consultation with superior authority.

6. Whenever a supply, in which significant change is recorded, can be, it should be withheld from use. If the supply cannot be withheld from use and/or cannot be removed promptly from the distribution system, warning should be given to the users of the supply by competent and responsible authority. Such warning should, if conditions permit, be accompanied either by advice concerning a method of purifying such portions of the water as must be used for drinking and food preparation, or by advice how and where safe drinking water can be obtained.

7. The guarding of exposed parts of water works systems against crackpots and individual saboteurs is clearly the duty of local authorities. On the other hand, the protection of water works systems against organized professional enemy groups is clearly beyond the province of the water supply utility. It, therefore, becomes necessary that protection of this type be afforded by the national government through the F.B.I. or other agencies.

Consequently, the engagement of a large number of guards or of laboratory technicians, thus withdrawing them from the war effort, is not recommended.

Any acts pertaining to the water supply utilities which might possibly involve a violation of a national security statute should be reported promptly to the nearest office of the F.B.I. so that appropriate action can be taken.

Federal Order Concerning Water Supply
(*Dominion of Canada*)

AN order-in-council passed on July 23, 1942 by the Dominion Government (*P.C. 5707) gives wide powers to the Department of Pensions and National Health in respect to the treatment of public water supplies, including taking over the management and operation of systems and charging the cost of such against the owners. The order reads as follows:

"WHEREAS under the provisions of the Department of Pensions and National Health Act the duties and powers of the Minister of Pensions and National Health extend to and include matters and questions relating to the promotion or preservation of the health of the people of Canada;

"AND WHEREAS the Minister of Pensions and National Health reports, in the opinion of the officers of the Department of Pensions and National Health, the water supplies in certain areas of Canada are impure to such an extent as to constitute a menace to the health of civilians engaged in essential war activities and to members of His Majesty's forces;

"AND WHEREAS it is deemed advisable for the security, defence and welfare of Canada to provide that the Minister of Pensions and National Health shall have power to provide for the treatment of impurities of any water supplies and to take such steps as may be necessary to prevent pollution of any water supplies;

"1. The Minister of Pensions and National Health or, with his concurrence, the Deputy Minister, may by order in writing direct that the owner or person in charge of any undertaking for the supply of water shall take such steps as the Minister or the Deputy Minister deems necessary for the purpose of treating such water for qualities inherent therein causing such water to be unsafe for human consumption or as a precaution against such water becoming unsafe for human consumption by the introduction therein of foreign matter.

"For the purposes of this section water shall be deemed to be unsafe for human consumption if it is not a potable water free from pathogenic bacteria and if it contains organisms of the colon group in excess of 1 per 100 cubic centimetres of the water determined by the presumptive test for bacteriological examination of water using Phelps' method of calculation.

"2. The Minister of Pensions and National Health or, with his concurrence, the Deputy Minister, shall take such steps as appear to said Minister or to the said Deputy Minister to be necessary or expedient to effect compliance with any direction made by him under paragraph one of this Order.

"3. In the event of non-compliance with any direction made under paragraph one of this Order the Minister of Pensions and National Health or, with his concurrence, the Deputy Minister, may authorize the Chief Sanitary Engineer of the Department of Pensions and National Health to take over in whole or in part the management, control and operation of the undertaking referred to in such direction and the said Minister may make such orders and do such things as he deems necessary to effect such taking over.

"4. The Minister of Pensions and National Health or, with his concurrence, the Deputy Minister, may purchase such supplies and employ such persons as may be necessary to carry out the provisions of this Order and all monies expended for such purposes may be recovered as a debt due to the Crown from the owner of the undertaking with respect to which such monies are expended.

"5. Any person who fails without reasonable excuse to comply with this order or with any order or direction made under this Order shall be guilty of an offence and liable on summary conviction to a fine of not less than one hundred dollars and not more than one thousand dollars or to imprisonment for not less than one month and not more than two years, or to both such fine and such imprisonment."

* It will be observed that the order includes:

(1) The assumption, by the Department of Pensions and National Health, of authority to direct what steps the persons in charge of a water supply shall take to maintain water quality;

(2) The assumption of authority (which may be delegated to the Chief Engineer of the Department of Pensions and National Health) to "take over in whole or in part the management, control and operation" of any water system;

(3) The assumption of authority to purchase such supplies and employ such persons as may be deemed necessary to carry out the purposes of the order. Such expenditures are indicated to be a "debt due to the Crown" and therefore recoverable from the water authority;

(4) The definition of a water as unsafe if (a) it contains organisms of

* Discussion by Harry E. Jordan, Secretary, A.W.W.A.

the colon group in excess of 1 per 100 cubic centimeters, (b) determined by the presumptive test, (c) using the Phelps method of calculation.

It appears from press comment originating within the Dominion that the order was discussed only to a limited degree with the various sanitary authorities within the Dominion. It also appears that it was not at all discussed with certain of the Provincial Sanitary Engineers and Municipal Water Engineers whose qualifications in Sanitary Engineering matters are recognized as ample by those who know them in the Dominion and within the United States.

It appears also that the promulgation of the order springs from differences of opinion concerning the need for chlorination of the Vancouver (B.C.) supply. This impounded, mountain-side supply has been carefully studied by various authorities. One of them, N. J. Howard, former, President of the A.W.W.A. and Director of Water Examination at Toronto reported that the organisms of the colon group found in the Vancouver supply were dominantly of the non-fecal type. He did not recommend against chlorination, but the Greater Vancouver Water District has and continues to oppose chlorination. It appears that the City of Vancouver will contest the validity of the order in court.

Should the Sanitary Engineering staff of the Department of Pensions and National Health have an opportunity to review and revise the Standard of Quality now set up, it may be well to consider certain facts.

The term "presumptive test" is defined in *Standard Methods*.* In that text (p. 215) it is clearly shown that the "presumptive" test is not recommended for application to a "finished" water, i.e., a water prepared for human consumption. The "completed" test is basically recommended. or as an alternate under limited conditions the "confirmed" test may be used.

The so-called Phelps method of computing the "Indicated Number" of coliform group organisms is only secondarily advised (p. 222 of *Standard Methods*). The multiple planting method leading to the computation of the "Most Probable Number" of coliform group organisms is the standard procedure.

The studies that have been made in many localities and by many persons indicate that if the "presumptive" test is used as a measure of coliform group density, at least twice the number of positive findings are likely to result, when comparing such findings with data derived from the "completed" test.

This means in effect that the new Canadian standard can be, in the case

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* *Standard Methods for the Examination of Water and Sewage*. Am. Public Health Assn. & Am. Water Works Assn., New York (8th ed., 1936).

of many water supplies, twice as drastic as the U.S. Drinking Water Standard. Since within the United States, in a certain court decision, the validity of the U.S. Standard has been questioned as an exact basis upon which safety of a water supply can be predicated, it will be necessary for the Canadian authorities to prepare themselves very adequately to demonstrate the validity of a standard doubly severe.

Underlying the above comments, which are made upon the basis of judgment of a professional water purification engineer, there exists a substantial doubt that the mandatory and authoritarian aspects of the order contribute to the cause or clarity of thinking of a free people—even though those people are at war.

If Canadian water supplies generally are unsafe and require federal operation and control in the interest of public as well as military health and safety, the fact has been well concealed. If problems related to a single supply or a small group of supplies have been magnified to the degree of importance that seemed to require a nation-wide edict, the traditional capacity of free people to reason together must have been lost in the temper of wartime activity.

Definitely, the standard as now promulgated cannot be expected to stand the test of complete engineering study and administrative judgment. A great deal of damage to Canadian institutions and governmental practices can be avoided by an amendment of the document.

It may well be remembered that a group of Americans, schooled in the best British tradition, said in Philadelphia more than one hundred and fifty years ago that the just powers of a government are derived from the consent of the governed. Today with administrative authority so much delegated to Boards and Commissions, it is well to remember that, in engineering and other professional matters, truth rests not in edicts but in the results of research appraised in reasoned discussion.